DIESEL-ELECTRIC RESIDUAL HEAT RECOVERY IN THE NORTHWEST TERRITORIES

A Feasibility Study

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DIESEL-ELECTRIC RESIDUAL HEAT RECOVERY
IN THE NORTHWEST TERRITORIES
A Feasibility Study

Prepared for:

Government of the Northwest Territories

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With a contribution from:

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ABBREVIATIONS

DG	DIESEL GENERATOR
DHW	DISTRICT HOT WATER
DHWR	DISTRICT HOT WATER RETURN
DHWS	DISTRICT HOT WATER SUPPLY
EHRS	EXHAUST GAS HEAT RECOVERY SILENCER
EXG	EXHAUST GAS
HRS	HEAT RECOVERY SYSTEM
HX	HEAT EXCHANGER
JW	JACKET WATER
NCPC	NORTHERN CANADA POWER COMMISSION
WTP	WATER TREATMENT PLANT

ABSTRACT

The process of converting fuel energy to electric power is relatively inefficient. High fuel costs in the Northwest Territories make it imperative to maximize the economic use of this energy source through cogeneration.

Cogeneration is the simultaneous, interrelated production of electricity and recoverable heat. Thermal power plants are inherently capable of cogeneration. Effective application of cogeneration to a given site requires an economical match of potential heating demands to the electrical characteristics.

The objectives of this study were to:

- Evaluate the performance of two existing diesel-electric residual heat recovery systems (at Cambridge Bay and Lac La Martre);
- Determine the potential for residual heat recovery from current and projected NWT diesel generating plants in 39 candidate communities;
- Match residual heat availability to the potential demand cycles for each site;
- Examine the economic viability of residual heat recovery at each site, considering the savings achieved and projected for the two existing installations.

The existing systems were found to be operating considerably below potential, due (in the case of Cambridge Bay) to a poor match between generator and user thermal characteristics or (in Lac La Martre) to apparent deterioration in component condition. Remedial measures were identified for both sites.

Analysis of the data obtained demonstrated available heat ranging from 0.9 to 1.1 kW from jacket water, plus 0.65 to 0.7 kW from exhaust gases, per kW of electrical output. By selection of users with compatible requirements, close to 100% of available energy can be recovered as space heat.

Ranking of the 39 candidate sites on the basis of projected savings from residual heat recovery against estimated capital costs showed the following simple payback periods:

For jacket water systems: - 16 sites: less than 10 years;
- 13 sites: from 10 to 20 years.

Including exhaust recovery: - 7 sites: less than 10 years:
- 19 sites: from 10 to 20 years.

The detailed comparisons contained in the report are intended to establish priorities for implementation of heat recovery in the Northwest Territories.

EXECUTIVE SUMMARY

Introduction

Electrical energy at communities in the Northwest Territories is generated primarily by diesel generating plants operated by the Northern Canada Power Commission (NCPC). The process of converting diesel fuel energy to electrical energy is relatively inefficient as conversion efficiency is only about 30 percent using conventional engine-driven generators. Typically, the remainder of the energy is lost through the cooling system (30 percent), the exhaust gas (30 percent), and radiation and miscellaneous losses (10 percent).

Because of the inherent benefits of residual heat recovery, some generating plants in the Territories have been modified or converted to recover and use the residual heat for district heating purposes. This study was undertaken to:

- evaluate the effectiveness of two existing residual heat recovery systems, one in Cambridge Bay (using jacket water only), and the other in Lac La Martre (using jacket water plus exhaust gas);
- determine the economic feasibility of providing similar installations at other candidate sites.

Objectives

Specific objectives of this study are paraphrased as follows:

A. To assemble construction, operating, and performance data for two existing heat recovery installations.

B. To evaluate and interpret data assembled from existing facilities to assess the designs, methods of operation, equipment, and materials used with the intent of optimizing heat recovery processes.

C. To apply the findings from A. and B. above to establish the technical and economic viability of recovering residual heat from the NCPC diesel-electric generating plant in each of 39 candidate sites in the Northwest Territories.

Methodology

Detailed monitoring of heat recovery and distribution facilities at Lac La Martre and Cambridge Bay was carried out during January and February of 1985.

Temporary instrumentation was installed at Cambridge Bay and Lac La Martre to measure and record flows and temperatures of engine exhaust gases, engine coolant, and heated water being used to collect and distribute residual heat. In addition, electrical power generation, fuel consumption, outdoor temperature and other data pertinent to the NCPC stations and residual heat user facilities were collected.

The data collected at Lac La Martre and Cambridge Bay was assembled and computer analyzed to provide the information for the technical and economic evaluations required for heat recovery systems and residual heat utilization. Where inaccuracies in the accumulated data were noted, as in exhaust gas flow (Lac La Martre) and fuel consumption (Cambridge Bay), manufacturers' characteristic values were substituted and the results checked logically against related parameters to ensure consistency. Conclusions drawn from the data evaluation at Lac La Martre and Cambridge Bay were extrapolated to apply to 37 other sites in the Northwest Territories to determine the technical and economic feasibility of installing residual heat recovery and district heating systems in these communities.

The data evaluation also provided a basis for recommendations regarding optimization of operation of residual heat recovery facilities.

Summary of Findings and Conclusions

General

1. The amount of heat readily available for recovery from a typical diesel generator plant per kW of electrical load ranges from 0.9 to 1.1 kW from the engine jacket water cooling system and from 0.65 to 0.7 kW from the exhaust gas system.

2. By proper choice of residual heat users, their locations and system controls, close to 100 percent of residual heat available can be recovered as hot water for space heating.

3. Recovery of residual heat from jacket cooling water is generally more practical and economically feasible

than total residual heat recovery from jacket water and exhaust gas.

Specific to Cambridge Bay and Lac La Martre

4. The total heat utilized from jacket cooling water at Cambridge Bay amounted to 45 percent of the total available residual heat from this source for the test period.

5. The total heat utilized from jacket cooling water plus exhaust gas at Lac La Martre amounted to 55 percent of the total available residual heat from these sources for the test period.

6. The jacket cooling water temperature returning from the heat recovery equipment to the engines is running in the 65 to 75°C range. This is below the engine manufacturer's recommended temperature and may lead to higher maintenance and premature failure of the units.

7. The exhaust gas temperature leaving the heat recovery (silencer) equipment is frequently below the dew point. Under these conditions, condensation and subsequent corrosion of the steel equipment and piping will occur.

8. The domestic hot water heating system temperature should be increased to at least 80°C for optimum utilization of available heat by the connected users.

9. Although the diesel generating units at Cambridge Bay are operated efficiently, those at Lac La Martre frequently operate at less than 50 percent load with resultant low thermal efficiency.

10. There are no scheduled maintenance programs for the residual heat recovery systems either at Lac La Martre or Cambridge Bay. NCPC staff are responsible to maintain the generators and engines but not the recovery equipment.

11. Valving and controls for the residual heat recovery equipment are mostly manual, and automatic features that do exist are not wholly effective. This results in erratic operation and control, less than optimum utilization of residual heat, and reversal of heat flow from user to the generator.

Other Sites

12. Depending upon location, design of facilities, electrical load and heat user demand, simple pay back of heat recovery equipment for NCPC stations in the Northwest Territories will vary from about three to well over 20 years (assuming efficient utilization of all the available heat), as detailed in the following tabulation.

	Simple Pay Back Period (Years) at 100% Heat Utilization		Annual Fuel Savings (1985)		
Site	Jacket Water Heat Recovery Only	Jacket Water and Exhaust Gas Heat Recovery	Jacket Water Heat Recovery Only	Jacket Water and Exhaust Gas Heat Recovery	Assessed[1] Degree of Difficulty to Install a Residual Heat Recovery System
Rankin Inlet	2.95	5.00	$161,218	$268,811	5-6
Igloolik	3.13	7.77	72,535	118,694	2-3
Spence Bay	5.09	7.06	74,255	121,508	3-4
Pelly Bay	4.40	7.66	39,197	64,140	2-3
Pangnirtung	5.37	13.83	59,742	97,760	8-9
Paulatuk	5.64	11.39	15,624	25,568	6-7
Fort McPherson	6.01	9.92	45,556	74,546	6-7
Lake Harbour	7.14	13.45	26,346	43,112	6-7
Aklavik	7.19	10.39	54,839	89,736	1-3
Sachs Harbour	7.77	10.94	37,970	62,132	3-4
Cape Dorset	8.12	7.07*	68,571	112,208	3-4
Broughton Island	8.27	18.86	30,663	50,176	3-5
Eskimo Point	8.45	15.39	63,976	104,688	3-5
Coral Harbour	9.18	8.08*	73,232	119,834	8-9
Fort Franklin	9.34	13.31	34,175	55,923	7-8
Arctic Bay	9.47	17.42	40,265	65,888	3-4
Coppermine	10.00	11.95	81,930	134,067	1-2
Rae Lakes	10.72	12.58	9,061	14,827	3-4
Pond Inlet	10.89	11.91	86,168	141,002	6-7
Gjoa Haven	11.20	10.82*	63,267	103,528	3-4
Fort Simpson	11.23	12.82	83,780	137,095	7-8
Hall Beach	13.83	12.68*	34,206	55,973	3-4
Whale Cove	14.11	17.32	20,194	33,044	6-7
Baker Lake	14.27	11.80*	118,680	194,204	2-3
Fort Liard	15.23	20.74	12,729	20,829	3-4
Repulse Bay	15.28	20.94	26,159	42,805	6-7
Fort Norman	15.34	18.42	21,900	35,836	7-8
Wrigley	16.04	67.71	7,252	11,867	3-4
Fort Good Hope	16.77	26.67	24,001	39,279	2-3
Grise Fiord	21.72	30.78	16,918	27,685	7-8
Holman Island	22.5	10.39*	34,580	56,585	3-4
Arctic Red River	22.20	35,83	8,408	13,758	0-1
Clyde River	32.15	28.03*	44,938	73,535	7-8
Snowdrift	38.85	33.53*	9,080	14,858	6-7
Chesterfield Inlet	74.58	36.70*	22,018	36,030	7-8
Nahanni Butte	78.40	99.59	2,747	4,496	3-4

Notes: 1. 0 rating represents an easy installation, 10 rating represents a difficult installation.

* Sites which have a shorter pay back period with heat recovery from both Jacket Water and Exhaust Gas.

Recommendations

General

1. The Government of the Northwest Territories should establish a priority list for implementing heat recovery from NCPC stations at various communities in the Northwest Territories, based on assessment of the calculated payback period presented in this report.

2. The Government of the Northwest Territories should renew discussions with NCPC regarding maintenance and operation of both existing residual heat recovery facilities and those planned for future implementation. Clear understanding of responsibilities and remuneration regarding operations and maintenance must be established to ensure optimum performance and hence economic justification of capital expenditures.

3. In future designs of residual heat recovery facilities, selective use of automatic controls can optimize heat utilization and prevent adverse conditions for the diesel engines. Provisions should also be made to prevent reverse heat flow (from user to NCPC).

4. In future designs of engine exhaust gas residual heat recovery facilities, consideration should be given to constructing heat exchanger and all downstream exhaust piping and stack of stainless steel. This will allow more heat extraction from this source without the problem of potential corrosion occurring due to condensation in equipment and piping.

5. Design heat recovery systems based on 1.1 kW of jacket water heat and 0.70 kW of exhaust gas heat per kW of electrical load. Base total load on the average annual load factor as provided by NCPC.

Specific to Lac La Martre

6. Overhaul diesel generator units to improve thermal efficiency and whenever possible use Diesel Generator No. 3 only, since it is more closely rated to the load and thereby provides considerably higher thermal efficiency than Diesel Generator No. 1.

7. Upgrade existing heat exchanger by installing an additional 24 plates. Concurrently, raise the jacket water inlet temperature to about 85°C, if possible (to allow 80°C heating water temperature), and upgrade controls to maintain temperature within the specified range of 74 to 91°C.

8. Install controls on exhaust gas heat recovery system to maintain the exhaust temperature in the 150 to 175°C range to prevent condensation.

Specific to Cambridge Bay

9. Replace existing heat exchangers with a unit designed to provide a domestic hot water supply temperature within 5°C of jacket water temperature. Attempts should also be made to maintain the jacket water inlet temperature at about 80°C.

10. Replace manual switchover control valves on the domestic hot water system at the GNWT Buildings with three-way motorized diverter valves.

11. Replace the three-way mixing valve at the water treatment plant with three-way motorized diverting valve.

RÉCUPÉRATION DE LA CHALEUR RÉSIDUELLE DE CENTRALES ÉLECTRIQUES AU DIESEL DANS LES TERRITOIRES DU NORD-OUEST

Résumé

Introduction

Ce sont surtout les génératrices diesel exploitées par la Commission d'énergie du Nord canadien (CENC) qui produisent l'énergie électrique dans les localités des Territoires du Nord-Ouest. Le processus de conversion de l'énergie du carburant diesel en énergie électrique est relativement peu efficace étant donné que le rendement n'est que d'environ 30 % dans le cas de génératrices classiques à moteur. En général, le reste de l'énergie se perd dans le système de refroidissement (30 %), dans les gaz d'échappement (30 %), et par rayonnement et diverses causes (10 %).

En raison des avantages inhérents de la récupération de chaleur résiduelle, certaines génératrices des Territoires du Nord-Ouest ont été modifiées ou converties de façon à récupérer et à utiliser la chaleur résiduelle pour le chauffage urbain. Cette étude a été entreprise pour:

- évaluer l'efficacité de deux systèmes existants de récupération de chaleur résiduelle, l'une à Cambridge Bay (qui n'utilise que l'eau de la chemise) et l'autre à Lac La Martre (qui utilise l'eau de la chemise ainsi que les gaz d'échappement);

- déterminer la faisabilité économique d'installations du même type dans d'autres endroits sélectionnés.

Objectifs

Les objectifs particuliers de cette étude sont les suivants:

A. Rassembler des données relatives à la construction, à l'exploitation et aux performances de deux installations existantes de récupération de chaleur.

B. Évaluer et interpréter les données recueillies à partir des installations existantes pour évaluer la conception, les méthodes d'exploitation, l'équipement et les matériaux utilisés en vue d'optimaliser le processus de récupération de chaleur.

C. Appliquer les résultats obtenus en A et B ci-dessus pour établir la viabilité technique et économique de la récuperation de chaleur résiduelle des centrales de la CENC dans chacun des 39 sites sélectionnés dans les Territoires du Nord-Ouest.

Méthodologie

La surveillance détaillée des installations de récupération et de distribution de chaleur à Lac La Martre et à Cambridge Bay s'est effectuée en janvier et en février 1985 par des instruments installés provisoirement pour mesurer et enregistrer les températures des gaz d'échappement des moteurs, du fluide de refroidissement des moteurs, et de l'eau qui sert à récupérer et à distribuer la chaleur résiduelle. En outre, la production d'énergie électrique, la consommation de combustible, la température extérieure et d'autres données pertinentes aux installations de la CENC et aux installations des utilisateurs de chaleur résiduelle, ont été relevées.

Les données recueillies à Lac La Martre et à Cambridge Bay ont été assemblées et analysées par ordinateur; on a ainsi obtenu les renseignements nécessaires aux évaluations techniques et économiques requises pour les systèmes de récupération de chaleur et pour l'utilisation de la chaleur résiduelle. Les conclusions tirées de l'évaluation des données relatives aux deux localités ci-dessus ont été extrapolées et appliquées à 37 autres sites des Territoires du Nord-Ouest, ce qui a permis de déterminer pour ces endroits, la faisabilité technique et économique de l'installation de systèmes de récupération de chaleur résiduelle avec chauffage urbain.

L'evaluation des données a aussi servi de base aux recommandations concernant l'optimalisation de l'exploitation d'installations de récupération de chaleur résiduelle.

SOMMAIRE DES RÉSULTANTS ET CONCLUSIONS

Généralités

1. La quantité de chaleur récupérable fournie par une génératrice diesel typique par kilowatt de charge électrique est de 1,1 kW de l'eau de refroidissement en chemise et de 0,65 kW des gaz d'échappement.

2. En choisissant convenablement le système de récupération de chaleur résiduelle, son emplacement et les commandes de systèmes, it est possible de récupérer près de 100 % de la chaleur résiduelle sous forme d'eau chaude pour le chauffage des locaux.

3. La récupération de la chaleur résiduelle de l'eau de refroidissement de la chemise est généralement plus pratique et plus économiquement faisable que la récupération totale de chaleur résiduelle de l'eau de chemise et des gaz d'échappement.

Particularités à Cambridge Bay et à Lac La Martre

4. À Cambridge Bay, la chaleur totale récupérée de l'eau de refroidissement de la chemise équivalait à 45 % de la chaleur résiduelle totale produite par cette source durant la période d'essai.

5. À Lac La Martre, la chaleur totale récupérée de l'eau de refroidissement de la chemise ainsi que des gaz d'échappement équivalait à 55 % de la chaleur résiduelle totale produite par ces sources durant la période d'essai.

6. La température de l'eau de refroidissement de la chemise dans le circuit de retour de l'équipement de récupération de la chaleur jusqu'aux moteurs oscille entre 65 et 75°C. Ce chiffre est inférieur à la température recommandée par le fabricant du moteur et peut aboutir à la hausse des frais d'entretien et à une défaillance prématurée des moteurs.

7. La température des gaz d'échappement à la sortie de l'équipement de récupération de chaleur est fréquemment inférieure au point de rosée. Dans ces conditions, il y aura condensation et corrosion intérieure de l'équipement et des canalisations d'acier.

8. La température du système de chauffage de l'eau domestique devrait être portée à au moins 80°C pour que les utilisateurs raccordés aux systèmes utilisent de façon optimale la chaleur fournie.

9. Bien que les génératrices diesel de Cambridge Bay soient exploitées efficacement, celles de Lac La Martre fonctionnent à moins de 50 % de la charge, ce qui entraîne un faible rendement thermique.

10. Il n'existe aucun programme d'entretien des systèmes de récupération de chaleur à Lac La Martre ou à Cambridge Bay. Le personnel de la CENC est responsable de l'entretien des génératrices et des moteurs, mais non pas de l'équipement de récupération de chaleur.

11. Les vannes et commandes de l'équipement de récupération sont surtout manuels, et les dispositifs automatiques existants ne sont pas entièrement efficaces. Il en résulte un fonctionnement et un contrôle erratiques, une utilisation de chaleur résiduelle inférieure aux conditions optimales et un refoulement du débit de chaleur de l'utilisateur en direction de la génératrice.

Autres sites

12. Selon l'emplacement, la conception des installations, la chaleur récupérable et la demande des utilisateurs, l'amortissement simple de l'équipement de récupération de chaleur des génératrices de la CENC varie d'environ trois à 20 années et plus (en présumant une utilisation rationnelle de toute la chaleur disponible), comme en témoigne le tableau suivant.

RECOMMANDATIONS

Généralités

1. Le gouvernement des Territoires du Nord-Ouest devrait établir un ordre de priorité pour la mise en oeuvre de systèmes de récupération de chaleur dans les centrales de la CENC situées dans diverses localités du Territoire en fonction de l'évaluation de la période d'amortissement calculée qui a été présentée dans ce rapport.

Site	Période d'amortissement simple (en années) avec utilisation de 100 % de la chaleur		Économies annuelles de combustible (1985)	
	Récupération de la chaleur de l'eau de la chemise seulement	Récupération de la chaleur de l'eau de la chemise et des gaz d'échappement	Récupération de la chaleur de l'eau de la chemise seulement	Récupération de la chaleur de l'eau de la chemise et des gaz d'échappement
Rankin Inlet	2.95	5.00	$161,218	$268,811
Igloolik	3.13	7.77	72,535	118,694
Spence Bay	5.09	7.06	74,255	121,508
Pelly Bay	4.40	7.66	39,197	64,140
Pangnirtung	5.37	13.83	59,742	97,760
Paulatuk	5.64	11.39	15,624	25,568
Fort McPherson	6.01	9.92	45,556	74,546
Lake Harbour	7.14	13.45	26,346	43,112
Aklavik	7.19	10.39	54,839	89,736
Sachs Harbour	7.77	10.94	37,970	62,132
Cape Dorset	8.12	7.07*	68,571	112,208
Broughton Island	8.27	18.86	30,663	50,176
Eskimo Point	8.45	15.39	63,976	104,688
Coral Harbour	9.18	8.08*	73,232	119,834
Fort Franklin	9.34	13.31	34,175	55,923
Arctic Bay	9.47	17.42	40,265	65,888
Coppermine	10.00	11.95	81,930	134,067
Rae Lakes	10.72	12.58	9,061	14,827
Pond Inlet	10.89	11.91	86,168	141,002
Gjoa Haven	11.20	10.82*	63,267	103,528
Fort Simpson	11.23	12.82	83,780	137,095
Hall Beach	13.83	12.68*	34,206	55,973
Whale Cove	14.11	17.32	20,194	33,044
Baker Lake	14.27	11.80*	118,680	194,204
Fort Liard	15.23	20.74	12,729	20,829
Repulse Bay	15.28	20.94	26,159	42,805
Fort Norman	15.34	18.42	21,900	35,836
Wrigley	16.04	67.71	7,252	11,867
Fort Good Hope	16.77	26.67	24,001	39,279
Grise Fiord	21.72	30.78	16,918	27,685
Holman	22.5	10.39*	34,580	56,585
Arctic Red River	22.20	35.83	8,408	13,758
Clyde River	32.15	28.03*	44,938	73,535
Snowdrift	38.85	33.53*	9,080	14,858
Chesterfield Inlet	74.58	36.70*	22,018	36,030
Nahanni Butte	78.40	99.59	2,747	4,496

• *Sites dont la période d'amortissement est plus courte en cas de récupération de chaleur de l'eau de la chemise et des gaz d'échappement.

2. Le gouvernement des Territoires du Nord-Ouest devrait reprendre les pourparlers avec la CENC au sujet de l'entretien et de l'exploitation des installations existantes de récupération de chaleur résiduelle et celles dont la mise en oeuvre est prévue pour l'avenir. Il faut définir clairement les responsabilités et les rémunérations au sujet des activités et de l'entretien pour assurer des performances optimales et pour assurer la justification économique des dépenses d'investissement.

3. Dans les modèles futurs d'installations de récupérateurs, l'utilisation sélective de commandes automatiques peut optimaliser l'utilisation de la chaleur et empêcher des conditions défavorables pour les moteurs diesel. Il faudrait aussi prévoir des dispositifs pour empêcher le refoulement du débit de chaleur (de l'utilisateur à la CENC).

4. Dans les modèles futurs d'installations de récupérateurs de la chaleur résiduelle des gaz d'échappement de moteurs, il faudrait envisager de construire en acier inoxydable les échangeurs de chaleur et toutes les canalisations et cheminées d'évacuation des gaz. Il sera ainsi possible d'extraire davantage la chaleur de cette source sans faire face au problème éventuel de corrosion dû à la condensation.

5. Concevoir des systèmes de récupération de chaleur à raison d'une récupération de 1,1 kW de chaleur de la chemise et de 0,65 kW des gaz d'échappement par kW de charge électrique. Fonder la charge totale sur le facteur annuel moyen de charge fourni par la CENC.

Particularités dans le cas de Lac La Martre

6. Effectuer une révision générale des génératrices diesel afin d'en améliorer le rendement thermique et utiliser autant que possible la génératrice diesel n° 3 uniquement, car elle convient plus adéquatement à la charge et fournit donc un rendement thermique considérablement plus élevé que le génératrice diesel n° 1.

7. Améliorer l'échangeur de chaleur existant de chemise en installant 24 plaques additionnelles. En même temps, porter à environ 85°C la température d'admission d'eau dans la chemise, si possible (pour obtenir un température d'eau de chauffage de 80°C), et améliorer les commandes afin de mainternir la température dans l'intervalle spécifié de 74 à 91°C.

8. Installer des commandes sur le système de récupération de chaleur des gaz d'échappement pour maintenir la température des gaz d'échappement dans la fourchette de 150 à 175°C afin d'empêcher toute condensation.

Particularités dans le cas de Cambridge Bay

9. Remplacer le échangeurs de chaleur existants par un échangeur conçu pour fournir une température d'alimentation en eau chaude domestique à 5°C près de la température de l'eau de la chemise. Il faudrait aussi essayer de maintenir à environ 80°C la température d'admission de l'eau dans la chemise.

10. Remplacer les vannes de commandes manuelles du circuit d'alimentation en eau chaude domestique dans les bâtiments du gouvernement des Territoires du Nord-Ouest par des vannes de dérivation à trois voies, à moteur.

11. Remplacer la vanne de mélange à trois voies située dans l'usine de traitement des eaux par une vanne de dérivation à moteur et à trois voies.

Cette étude a été préparée pour le gouvernement des Territoires du Nord-Ouest par Dillon Consulting Engineers & Planners avec une subvention d'Énergie, Mines et Ressources Canada dans le cadre du Programme de démonstration dans les collectivités éloignées.

GOVERNMENT OF THE NORTHWEST TERRITORIES DIESEL-ELECTRIC RESIDUAL HEAT RECOVERY

1. INTRODUCTION

1.1 General

The Northern Canada Power Commission (NCPC) operates diesel-electric generating plants throughout the Northwest Territories. As a general rule, the by-product heat is wasted by conventional fan-cooling of jacket water radiators, and direct atmospheric discharge of hot exhaust gases. To a limited extent, NCPC have used a small portion of readily recoverable jacket heat for heating of their plant buildings, and for preheating of heavier fuel oils.

In 1976, a policy of selective residual heat utilization was adopted jointly by Government of the Northwest Territories (GNWT) and NCPC, commencing with the Cambridge Bay system which was commissioned in 1977. Since that time, systems of varying complexity and efficiency have been installed in Fort Simpson, Igloolik, Fort Franklin, Rankin Inlet, Pelly Bay, and Lac La Martre. These systems are described in Section 2 of this report.

A number of studies have been conducted in the Northwest Territories (NWT) over the past six years dealing with existing and proposed installations, and also developing a general overview of heat recovery possibilities. However, no single document provides a comprehensive inventory of these sites with substantiated potential for both practical recovery and feasible, cost-effective utilization.

In November 1984, M. M. Dillon Limited was retained to conduct a new study, to provide the GNWT with a co-ordinated evaluation of residual heat recovery (RHR) to assist in meeting their "intent .... (which is) to increase the use of this resource ... and to maximize the economic benefits of both the existing and any new installations".

1.2 Study Objectives

The Study Management Committee, which consists of representatives from Federal Energy, Mines and Resources, NCPC, and various interested divisions of the GNWT, provided summary guidelines for the study which can be paraphrased as follows:

A. To assemble construction, operating, and performance data for two existing heat recovery installations.

B. To evaluate and interpret data assembled from existing facilities to assess the designs, methods of operation, equipment, and materials used with the intent of optimizing heat recovery processes.

C. To apply the findings from A. and B. above to establish the technical and economic viability of recovering residual heat from the NCPC diesel-electric generating plant in each of 37 candidate sites in the Northwest Territories.

The complete original Terms of Reference are included in Appendix "A" of this report.

2. EXISTING SYSTEMS

2.1 General

In the following, outline descriptions are presented of the residual heat recovery and utilization facilities that have been installed in the Northwest Territories to date. In depth descriptions are provided for facilities at Cambridge Bay and Lac La Martre since they were the subject of the monitoring and assessment study.

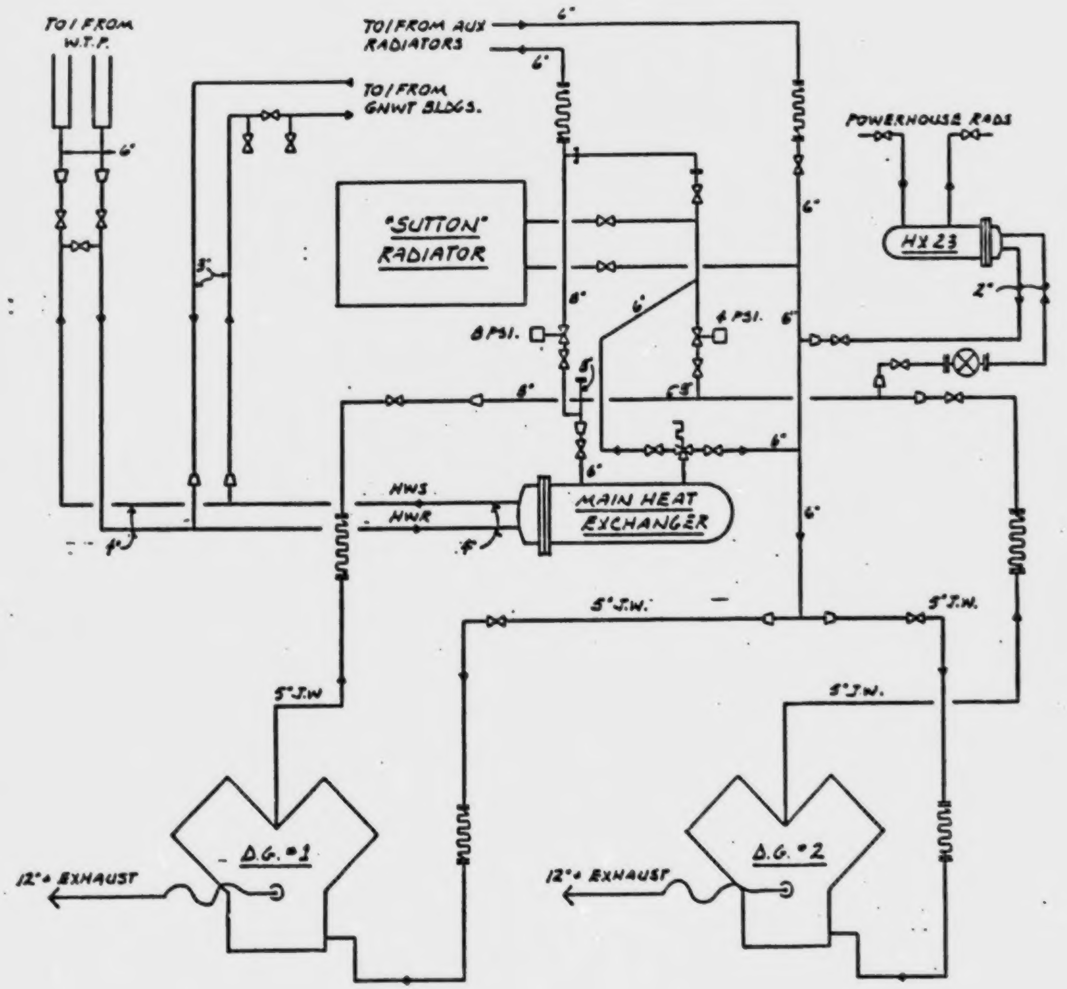
2.2 Cambridge Bay

This system is of particular interest, not only because it was the first joint venture by NCPC and GNWT for recovery and consumer utilization of diesel-generator residual heat, but also because it is the only NCPC/GNWT system servicing multiple points of use.

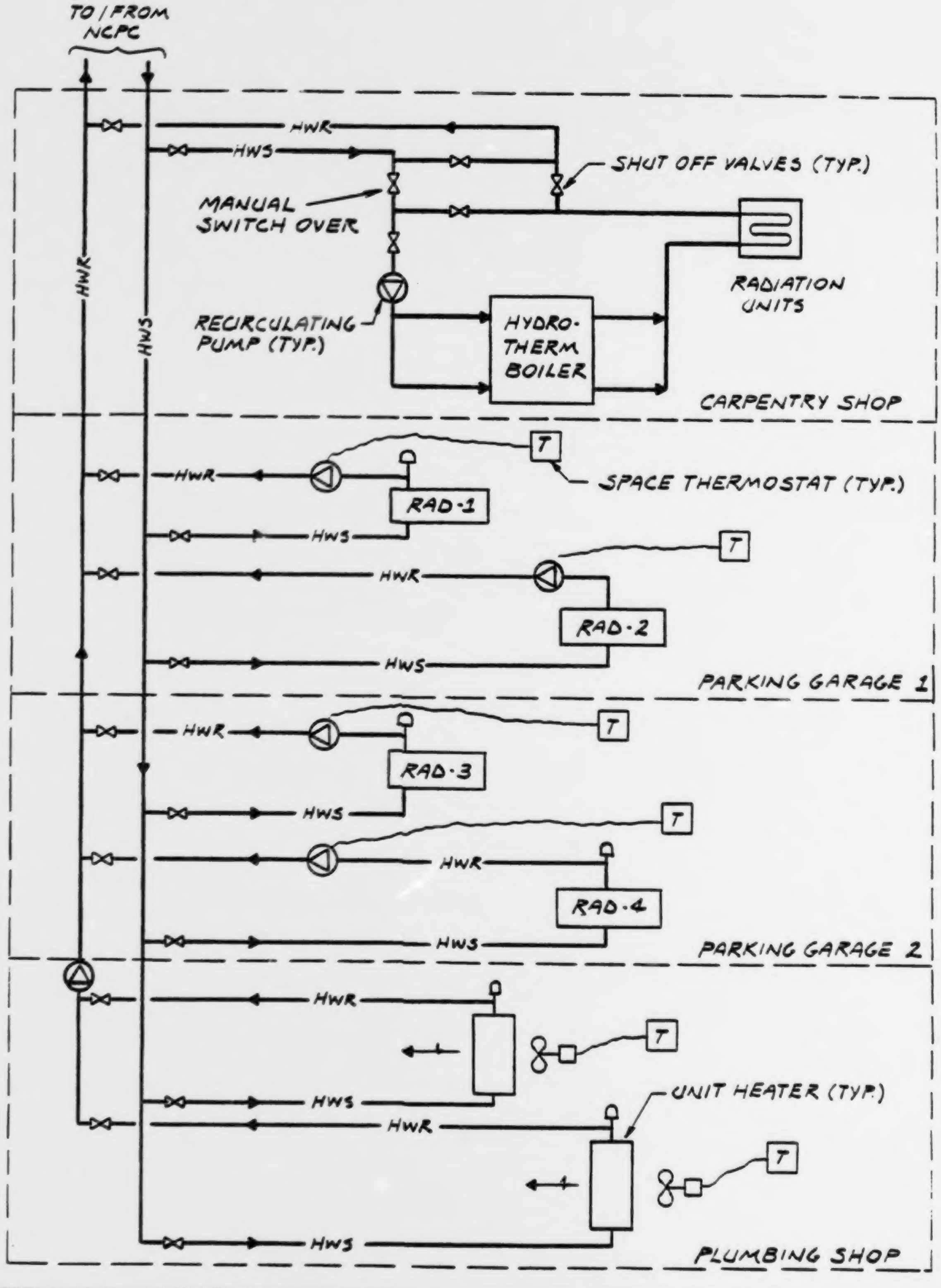
A flow schematic of the heat recovery system within the NCPC plant is presented in Figure 1.

The original 1977 installation provided recovered jacket-water heat to an immediately adjacent complex of GNWT workshops and storage buildings. Existing boilers in these buildings are interconnected with the single circulating hot-water loop by manual isolation valves as shown in Figure 2. (It is possible, if boiler controls are set above the circulating water temperature, for the boilers to cut in and raise the temperature of the return water above NCPC's supply temperature, resulting in boiler heat being wasted to atmosphere via the NCPC radiators.)

A second loop was installed in 1979 to supply heat to a new Water Treatment Plant, located approximately 200 metres northeast of the NCPC plant. The existing shell-and-tube


TO/FROM W.T.P.
6"
TO/FROM AUX RADIATORS
6"
6"
TO/FROM GNWT BLDGS.
3"
"SUTTON" RADIATOR
POWERHOUSE RADS
HX 23
2"
6"
8"
8 PSI.
4 PSI.
6"
6"
5"
8"
6"
6"
HWS
HWR
MAIN HEAT EXCHANGER
4"
4"
6"
5" J.W.
5" J.W.
5" J.W.
5" J.W.
D.G. #1
D.G. #2
12" ⌀ EXHAUST
12" ⌀ EXHAUST

DILLON | RESIDUAL HEAT RECOVERY SYSTEM | CAMBRIDGE BAY | FIG. No. 1


TO / FROM NCPC
HWR
HWS
SHUT OFF VALVES (TYP.)
MANUAL SWITCH OVER
RADIATION UNITS
RECIRCULATING PUMP (TYP.)
HYDRO-THERM BOILER
CARPENTRY SHOP
T
SPACE THERMOSTAT (TYP.)
RAD-1
RAD-2
PARKING GARAGE 1
RAD-3
RAD-4
PARKING GARAGE 2
UNIT HEATER (TYP.)
PLUMBING SHOP

DILLON	CAMBRIDGE BAY - PART OF EXISTING RESIDUAL HEAT DISTRIBUTION SYSTEM	FIG No. 2

heat exchanger and ancillary primary side piping were not modified. Subsequently in 1983, this loop was extended from the Water Treatment Plant to a new Arena and GNWT Regional Office complex, without changes at source. In both these facilities, modulating thermostatically controlled 3-way mixing valves were provided between the recovery loop and the building stand-by boilers, to prevent feedback of boiler heat.

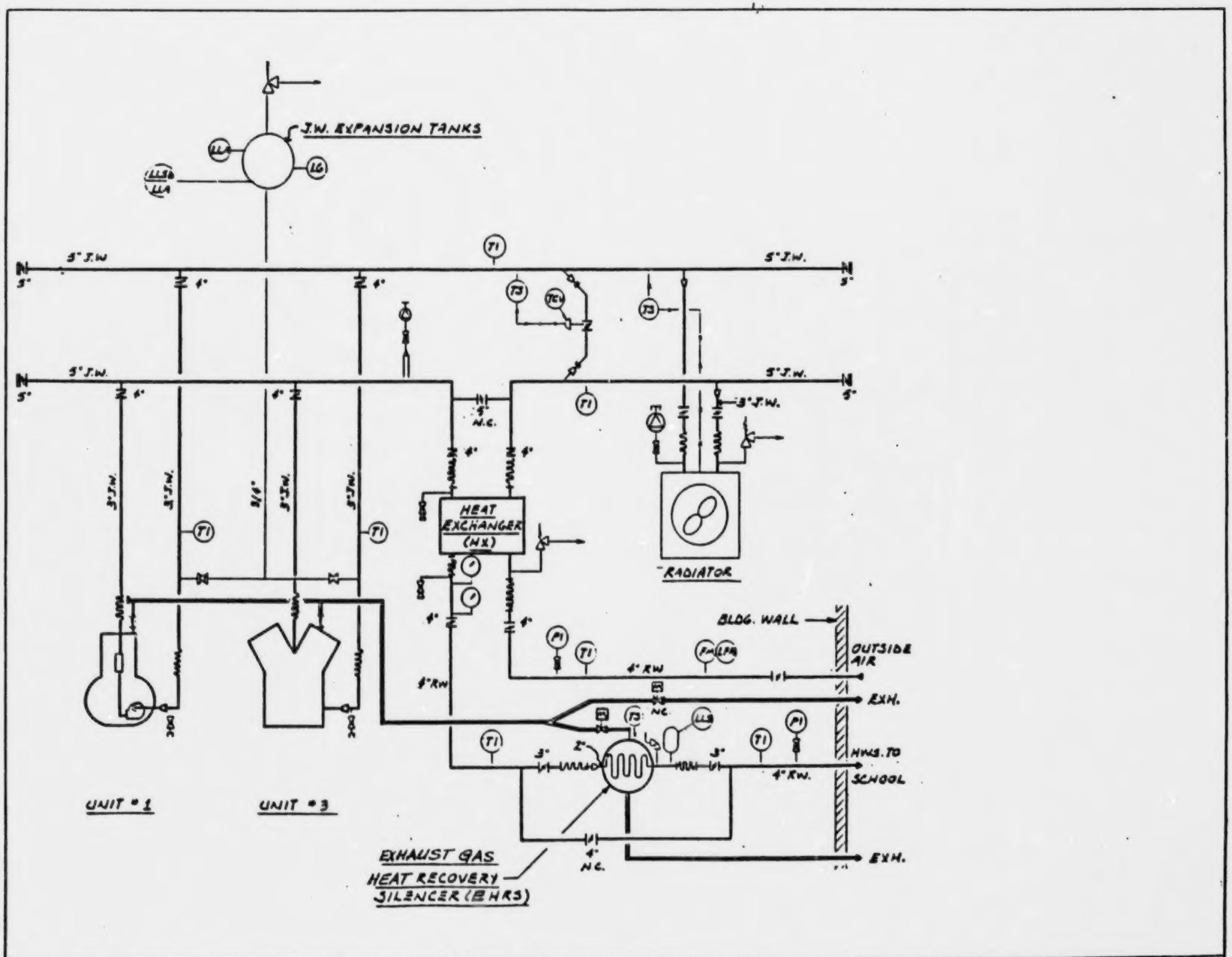
The system has performed well, despite shortcomings in automatic controls, largely because of the interest shown in it by management and staff of both NCPC and GNWT/DPWH.

There is considerable local interest in upgrading and expanding the residual heat facility, and in including exhaust gas heat recovery to improve the quality of heat supplied to points of use. There is also excellent potential within this community for expansion of the residual heat distribution system to other major buildings, existing and planned.

2.3 Lac La Martre

This is the most recent heat recovery installation by GNWT/NCPC, and as shown in Figure 3, the only one with exhaust heat recovery. It was installed in 1982 to serve the school and, although classed as a "retrofit", was the basis for the school heating system design. Design parameters for heat recovery equipment were dictated by the school's energy requirements.

The system performed very satisfactorily during its first year of operation, exceeding the expectations of the designers. During the summer of 1983 modifications were made to


J.W. EXPANSION TANKS
LLA
LG
LLSD
LLA
TI
5" J.W.
5"
5" J.W.
5"
4"
4"
TS
TCV
TS
5" J.W.
5"
5" J.W.
5"
4"
4"
5"
N.C.
TI
3" J.W.
4"
4"
3" J.W.
3" J.W.
3/4"
3" J.W.
3" J.W.
TI
TI
HEAT
EXCHANGER
(HX)
RADIATOR
4"
4"
BLDG. WALL
PI
TI
4" RW
FM
LFA
OUTSIDE
AIR
EXH.
4" RW
N.C.
TS
LLS
2"
3"
3"
TI
TI
PI
HWS. TO
SCHOOL
4" RW.
4"
N.C.
EXH.
UNIT # 1
UNIT # 3
EXHAUST GAS
HEAT RECOVERY
SILENCER (EHRS)

DILLON | RESIDUAL HEAT RECOVERY SYSTEM | LAC LA MARTRE | FIG. No. 3

the diesel plant, and concurrently flow and temperature gauges were installed to facilitate monitoring of performance. Some of the new controls have since been disconnected without regard for function.

In the 1983/84 heating season, heat recovery (as judged by demands on the school's own oil-fired boiler plant) was observed by local GNWT personnel to be less effective. It appears that this knowledge was not reflected in data provided to GNWT/ DPWH engineers in Yellowknife, and that records from this period are unreliable. In the fall of 1984, NCPC repair crews discovered a malfunction of the diverter valves controlling gas flow to the exhaust heat exchanger. Repairs were made. However, site visits by GNWT and Dillon personnel in November 1984 and since then have revealed no evidence of improvement in system efficiencies.

2.4 Rankin Inlet

A limited jacket water recovery system was installed by NCPC in 1975 for heating of their new office/garage building. It was modified in 1978 for diesel fuel preheating, and again in 1979 to supply an adjacent GNWT trades shop. Operation, which is essentially handled by NCPC alone, has been routine. Since the proportion of heat recovered is small and no revenue is obtained, there has been no attempt to accumulate operating data.

Currently, interest is being shown by the Hamlet, GNWT, and NCPC, in the potential for a significant increase in residual heat utilization in the following closely-grouped facilities:

- Williamson Lake Water Pumphouse (existing)
- 40-Unit Student Residence (completed 1984)
- Recreation Centre (anticipated completion 1985)
- 45-Unit Housing Development (anticipated 1986-87)
- High School (1985 design for 1988 completion)

The pumphouse pretempering system alone represents a design load of 122 kW, or approximately 17 percent of the jacket water heat available. This residual heat could be readily utilized by the pretempering system due to the low temperature levels required and the proximity of return water mains to the NCPC plant.

2.5 Igloolik

The original heat recovery system, installed between 1976 and 1978 using redundant pumps and exchangers from the diesel plant, provided heat from jacket water to a NCPC garage and (on an intermittent basis) to the Hamlet's Recreation Centre. In 1982, freezing of the secondary side of the recovery exchanger (reportedly due to misunderstanding of GNWT maintenance responsibilities) caused a total failure of the generator cooling and heat reclamation circuits. Recovery efforts were then discontinued.

Following negotiations between NCPC and GNWT, a new system was designed and installed to supply heat to an extended Recreation Centre which now included a swimming pool. The system has had a few operating difficulties (reportedly stemming from secondary control complexities), but has been generally satisfactory. NCPC obtain no revenue and have collected no data on this operation. No other source of data has been identified.

2.6 Fort Simpson

In 1981, connections were made from the NCPC plant to the raw water pumphouse 25m to the north, to activate a previously installed heat recovery system for tempering of raw water before transfer to the treatment plant. By design, this system was intended to extract 313.6 kW of heat at a temperature of 60°C. Due primarily to problems with the river intake, this system has not operated continuously and no serial data are available.

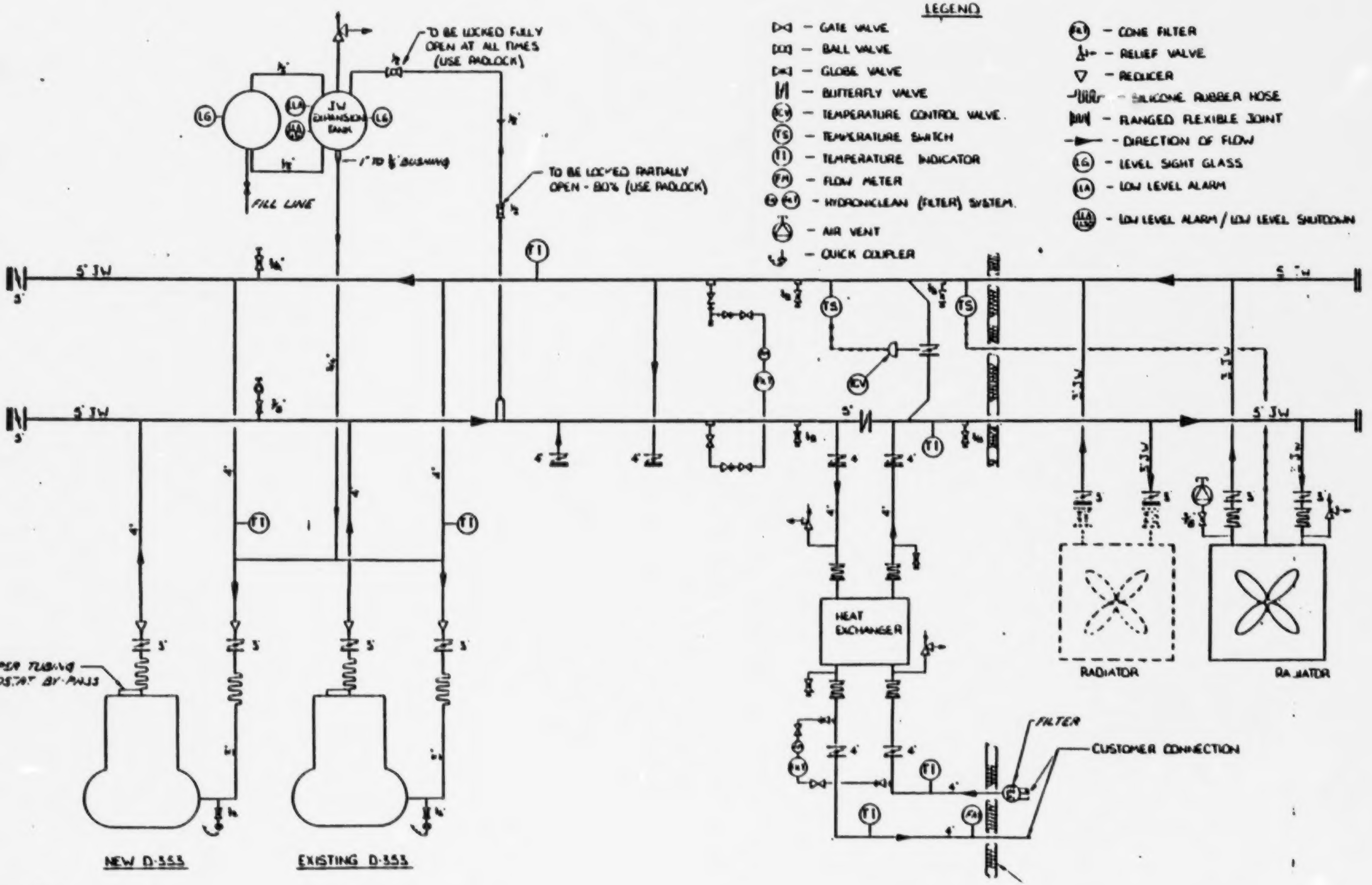
2.7 Pelly Bay

A single loop, as shown in Figure 4, to recover jacket water heat was installed in 1979/80, to supply the Pelly Bay Community Complex with residual heat from the NCPC plant. The system has operated well, supplying in excess of the heat required by the complex, until recently when the gymnasium floor slab cracked, rupturing the embedded heating pipes and necessitating their isolation.

This installation is essentially unattended, and NCPC have collected no data on its operation to date.

2.8 Fort Franklin

An internal heat recovery system was installed by NCPC in 1978. A 1983 proposal (Ferguson Simek Clark) to extend the residual heat to the new school is now being considered. No operating data are available.


LEGEND
GATE VALVE
BALL VALVE
GLOBE VALVE
BUTTERFLY VALVE
TEMPERATURE CONTROL VALVE
TEMPERATURE SWITCH
TEMPERATURE INDICATOR
FLOW METER
HYDROCLEAN (FILTER) SYSTEM
AIR VENT
QUICK COUPLER
CONE FILTER
RELIEF VALVE
REDUCER
SILICONE RUBBER HOSE
FLANGED FLEXIBLE JOINT
DIRECTION OF FLOW
LEVEL SIGHT GLASS
LOW LEVEL ALARM
LOW LEVEL ALARM / LOW LEVEL SHUTDOWN
TO BE LOCKED FULLY OPEN AT ALL TIMES (USE PADLOCK)
TO BE LOCKED PARTIALLY OPEN - 80% (USE PADLOCK)
J.W. EXPANSION TANK
1" TO ½" BUSHING
FILL LINE
5" JW
HEAT EXCHANGER
RADIATOR
RADIATOR
FILTER
CUSTOMER CONNECTION
¼" COPPER TUBING THERMOSTAT BY-PASS
NEW D-353
EXISTING D-353

PELLY BAY - J.W. HEAT RECOVERY FLOW SCHEMATIC

FIG. No. 4

3. POTENTIAL HEAT RECOVERY FROM NCPC STATIONS

3.1 Operating and Maintenance History

An important consideration in assessing the heat recovery potential at NCPC sites is the downtime of both the diesel generator sets (the heat source) and the recovery equipment (heat exchangers, circulation pumps, controls).

It was evident from discussions with NCPC personnel and plant operators that there is minimal data available on the operating and maintenance history of the NCPC stations. The opinion expressed by NCPC personnel was that seldom, if ever, was the heat recovery equipment down as a result of engine downtime. Pressed for a numerical estimate, NCPC estimated that the heat recovery system (HRS) may experience up to 2 percent operating and maintenance downtime. NCPC further advised that they schedule an annual routine overhaul of the generating equipment but do not schedule for general maintenance. The overhaul work is scheduled for the summer and estimated to take from 23 to 360 hours per engine annually.

The following equipment downtime was incurred during the study period:

- Cambridge Bay
  - HRS down for four days for piping modifications to the new jacket water (JW) cooling radiators.
  - A power outage of approximately one hour duration.

- Lac La Martre - HRS was down for 1 1/2 to 2 days due to controls malfunction

From discussions with the plant operators and a review of the available reports, several other recent equipment downtimes were noted. These were as follows:

- Lac La Martre - HRS was down, in September 1984 for an unknown duration for maintenance work on the exhaust gas diverter valves.
- Rankin Inlet - Heat supply to Trades Shop/ Mechanical Garage failed for approximately three hours.
- Igloolik - Failure of HRS due to freezing on secondary side of heat exchanger (HX) in September 1982.
- Ft. Providence - Polyethylene distribution pipe failed due to radial cracks and was replaced with polybutylene pipe.

In summary, there is a scheduled maintenance program established by NCPC for the generating equipment while no similar program exists for the HRS. NCPC's position appears to be that their responsibility ends at the primary side flanges to the HX. NCPC feels that from this point operating and maintenance should be the end user's responsibility. However, the end user's right of access into the generating station appears to be limited by NCPC staff who maintain control of (locked) access.

3.2 Load Forecasts

To determine the operating characteristics and limitations of the other NCPC generating stations, existing reports and equipment data were reviewed and discussions were held with NCPC personnel.

It is evident from the condensed NCPC data presented in Table 1 that the forecast total power generation and peak load are expected to grow at a rate ranging from 1 to 4 percent depending on the site. Furthermore the installed capacity is generally at least two times greater than peak load, generating at least 100 percent stand-by.

3.3 Heat Recovery Equipment Installation

To evaluate the ease of installing residual heat recovery equipment within the existing NCPC stations, discussions were held with NCPC Head Office personnel. They advised that any heat recovery system being contemplated should be designed so as not to interfere or otherwise restrict the normal operation of the generating plant. An assessment system was devised with space availability as the sole criterium.

The results of this assessment (whereby a 0 rating represents an easy installation and 10 represents a difficult installation) are presented in Table 2. Due to the lack of drawings for the candidate sites, the evaluation is based strictly on NCPC's comments.

TABLE 1

HISTORIC AND FORECAST ELECTRICAL ENERGY REQUIREMENTS

Site	Total Installed Capacity kW	Forecast[1] Average Annual Growth (%)		1985-86 Forecast Electrical Energy Requirements		
		Total Generation	Peak Load	Generation MWH	Peak Load kW	Load Factor %
Aklavik	1500	1.5	1.7	2426	577	48
Arctic Bay	1050	2.8	2.7	1361	353	44
Arctic Red River	280	3.3	3.2	404	69	67
Baker Lake	2174	2.5	2.4	4188	839	57
Broughton Island	630	0.4	0.5	1174	231	58
Cambridge Bay	2375	2.3	2.4	4940	1044	54
Cape Dorset	1500	3.4	3.5	2675	611	50
Chesterfield Inlet	650	1.1	1.3	820	199	47
Clyde River	1100	1.7	1.7	1637	322	58
Coppermine	1575	2.9	2.9	2901	676	49
Coral Harbour	1350[2]	3.7	3.7	2753	655	48
Eskimo Point	1800	2.9	2.8	3386	743	52
Fort Franklin	800	3.0	3.2	1439	401	41
Fort Good Hope	900	0.4	0.3	1254	349	41
Fort Liard	735	1.6	1.4	679	138	56
Fort McPherson	1280	0.4	0.4	2442	634	44
Fort Norman	950	1.1	1.1	1207	320	43
Fort Simpson	5485	0.8	0.8	5698	834	78
Gjoa Haven	1160	4.4	4.5	1807	449	46
Grise Fiord	415	2.2	2.3	561	128	50
Hall Beach	785	2.2	2.0	1207	230	60
Holman Island	850	2.2	2.2	1085	263	47
Igloolik[3]	1200	3.3	3.4	2567	543	54
Jean Marie River	61	8.4[4]	8.5[4]	56	19	34
Lac La Martre	455	0.1	0.1	503	171	42
Lake Harbour	750	1.4	1.3	1068	214	57
Nahanni Butte	151	2.5	2.3	96	21	53
Pangnirtung	1800	1.8	1.9	2761	671	47
Paulatuk[5]	300	6.7	6.7	672	207	37
Pelly Bay	800	2.2	2.4	961	228	48
Pond Inlet	1620	4.1	4.3	2986	696	49
Rae Lakes	260	0.3	0.2	278	86	37
Rankin Inlet	2720	5.4	5.3	7574	1572	55
Repulse Bay	750	0.1	0.1	1163	218	61
Sachs Harbour	800	2.7	2.8	1251	255	56
Snowdrift	430	1.6	1.7	553	140	45
Spence Bay	900	4.1	3.9	2064	512	46
Whale Cove	650	0.4	0.5	758	166	52
Wrigley	480	2.6	2.7	405	52	89

NOTES TO TABLE 1:

1. Average annual growth based on the forecast total percent growth from 1983-84 to 1989-90 divided by the number of years.

2. There are two DG stations at this site - a 600 kW station downtown and a 750 kW station by MOT.

3. Existing generating capacity will be increased from 1200 kW to 1500 kW in 1985 by replacing one of the two existing 300 kW units with a 600 kW unit.

4. This value is unrealistic because the 1983-84 base year was well below the previous year's generating capacity. If 1982-3 was the selected base year, average growth would be 1.6%.

5. Existing generating capacity will be increased in 1985 from 300 kW to 575 kW by installation of a new 275 kW DG unit.

As noted in Table 2, it will be difficult to install heat recovery equipment at some of the sites. This is particularly evident at Pangnirtung, where NCPC advised space is very tight.

A detailed presentation of the information relating to the existing diesel generator (DG) units at each candidate site is presented in Appendix B. The data highlights the jacket cooling water pump rating, expected temperature rise, exhaust system capacity, volume and temperature of combustion gases, plus other information necessary for proper design of a heat recovery system.

TABLE 2

INSTALLATION DIFFICULTY INDEX

Site	Assessed[1] Degree of Difficulty to Install a Residual Heat Recovery System
Aklavik	1-3
Arctic Bay	3-4
Arctic Red River	0-1
Baker Lake	2-3
Broughton Island	3-5
Cambridge Bay	1-3 (System partly installed)
Cape Dorset	3-4
Chesterfield Inlet	7-8
Clyde River	7-8
Coppermine	1-2
Coral Harbour	8-9
Eskimo Point	3-5
Fort Franklin	7-8
Fort Good Hope	2-3
Fort Liard	3-4
Fort McPherson	6-7
Fort Norman	7-8
Fort Simpson	7-8
Gjoa Haven	3-4
Grise Fiord	7-8
Hall Beach	3-4
Holman Island	3-4
Igloolik	2-3
Jean Marie River	3-4
Lac La Martre	(System already installed)
Lake Harbour	6-7
Nahanni Butte	3-4
Pangnirtung	8-9
Paulatuk	6-7
Pelly Bay	2-3
Pond Inlet	6-7
Rae Lakes	3-4
Rankin Inlet	5-6
Repulse Bay	6-7
Sachs Harbour	3-4
Snowdrift	6-7
Spence Bay	3-4
Whale Cove	6-7
Wrigley	3-4

NOTES:

1. 0 rating represents an easy installation, 10 rating represents a difficult installation.

4. MONITORING OF EXISTING SYSTEMS

4.1 General

It was established in the Terms of Reference that two existing residual heat recovery installations, namely Cambridge Bay and Lac La Martre, were to be monitored in detail. These sites were selected in the expectation that they would demonstrate two quite different approaches to residual heat utilization, respectively:

a) Distribution of low-quality heat from a jacket-water source to multiple points of use (Cambridge Bay).

b) Supply of high-quality heat to a single large user (Lac La Martre).

The comparative systems had further differences of significance, such as the former having round-the-clock operators and the latter being unmanned, and the former having been entirely retrofitted while the latter was largely custom-designed for residual heat recovery.

Since neither site had existing data recording equipment on the heat recovery circuits, installation of complete instrumentation packages was required for this study.

Reference literature on these instrumentation packages is included in Appendix "C-1".

To avoid extended generation plant outages for monitoring device installation, non-invasive primary sensor elements were specified wherever they could be expected to provide an acceptable level of accuracy. For the parameters of interest to this study, the following were used:

Power: Plug-in connections to each plant's existing potential and current-transformer test blocks.

Temperature: Type J thermocouples, spot-welded on to the exterior of pipes and snugly insulated to minimize gradient.

Gas Flow: There are no non-invasive elements available for gas flows, and therefore the averaging pitot-tube sensor ("Annubar" or equivalent) was selected as the least problematic option.

Liquid Flow: "Doppler" ultrasonic velocity meter (with twin transducers as required to obtain stable readings on relatively clean liquids) were installed, except where Annubars were already in place (Lac La Martre) or where piping sections could be temporarily isolated for installation of similar invasive elements.

Generator readings were compared with NCPC instrumentation, and thus demonstrated to be accurate. Temperatures were checked against existing thermometers in place.

All annubars and associated differential pressure transducers were calibrated against a portable test manometer. Since no tappings were available, ultrasonic meters were checked for accuracy against each other.

Since the power plants in which this instrumentation was to be placed were known to be poorly grounded, shielded cable was required to control electromagnetic interference with the signals between sensor elements and the acquisition unit.

The monitoring program was designed to generate a data base from which to:

- evaluate the effectiveness of the existing jacket water heat recovery/distribution system, and
- to make recommendations regarding system improvements.

Furthermore, the data were to be used to evaluate the viability of similar heat recovery and distribution systems at 37 other candidate sites in the NWT.

Difficulties were experienced in installing or in operating a number of the monitored parameters. Resultant data discrepancies were rationalized in the input evaluation, and sub-routines were set up in the computerized analysis procedures to make comparisons and adjustments as appropriate. The following discussion explains the logic and the calculative cross-checks employed where necessary to validate the data on which subsequent conclusions were based.

Detailed results of the monitoring program are presented in Appendix "C-2".

4.2 Cambridge Bay

4.2.1 Installation and Operation of Monitoring Equipment

Monitoring equipment was installed at the points as noted in Figure 5. Each of the sensors was connected to a Kaye Data Logger and set to record the measured parameter at five-minute intervals.

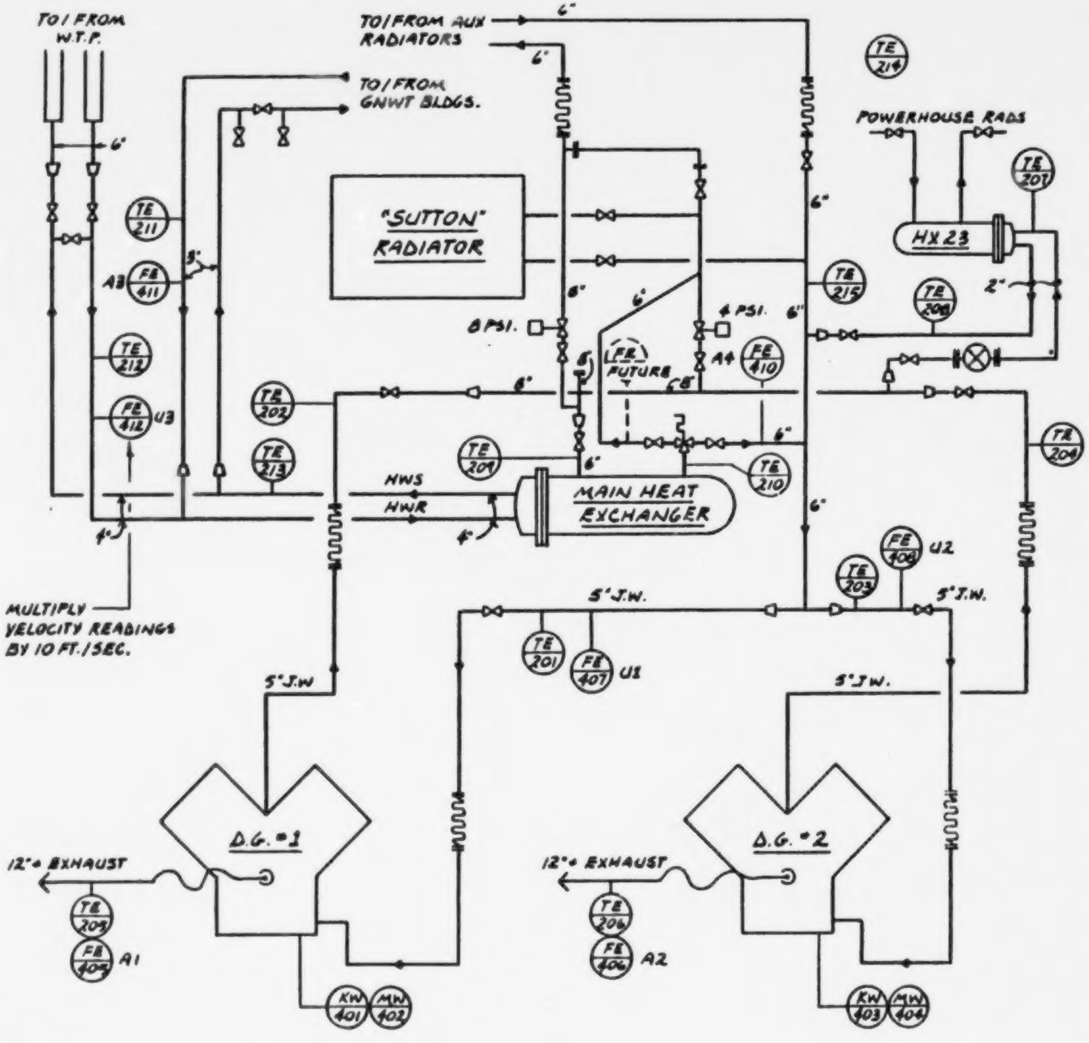
The ultrasonic meters employed for jacket water (JW) flow (FE 407 and FE 408) indicated significant velocities during no-flow conditions. This is believed to have been caused by high levels of audible and/or electromagnetic ambient noise, both of which were typical of conditions in the area of the plant in which the devices were located. Cable shielding was earthed, with no apparent effect. However, the occurrence of flow produced a signal that overrode the effect of the noise. Since it was standard operating procedure to manually close the jacket water isolating valves on the stand-by generator, it can be said that no generation (as indicated by KW 401 or KW 403) can also indicate no flow in the appropriate line (FE 407 or FE 408 respectively); therefore, at times of zero power generation, flow would be set to zero in the data analysis.

The readings recorded against FE 412 were also found to be erroneous, but in this case because of a decimal-point error in the Digistrip program. Correction of this error necessitated the imposition of a multiplier during analysis.

4.2.2 Discussion of Results

a) Jacket Water System

Data for the inlet jacket water (JW) temperature to the diesel generators (DG), as presented on Figure 6, for a


TO/FROM W.T.P.
6"
TE 211
A3
FE 411
3"
TE 212
FE 412
U3
4"
MULTIPLY VELOCITY READINGS BY 10 FT./SEC.
TO/FROM AUX RADIATORS
6"
TO/FROM GNWT BLDGS.
6"
"SUTTON" RADIATOR
8 PSI.
6"
6"
FE FUTURE
CE
4 PSI.
A4
FE 410
6"
TE 202
TE 213
TE 209
HWS
HWR
4"
MAIN HEAT EXCHANGER
TE 210
6"
6"
TE 215
TE 214
POWERHOUSE RADS
TE 207
HX 23
2"
TE 208
TE 204
TE 203
FE 408
U2
5" J.W.
5" J.W.
TE 201
FE 407
U1
5" J.W.
5" J.W.
D.G. #1
D.G. #2
12"⌀ EXHAUST
12"⌀ EXHAUST
TE 205
FE 405
A1
TE 206
FE 406
A2
KW 401
MW 402
KW 403
MW 404

LEGEND

TE 201	Jacket Water Supply Temp. (°C) to DG #1
TE 202	Jacket Water Discharge Temp. (°C) from DG #1
TE 203	Jacket Water Supply Temp. (°C) to DG #2
TE 204	Jacket Water Discharge Temp. (°C) from DG #2
TE 205	DG #1 Exhaust Gas Temp. (°C)
TE 206	DG #2 Exhaust Gas Temp. (°C)
TE 207	Supply Water Temp. to HX 23 (°C)
TE 208	Discharge Water Temp. from HX 23 (°C)
TE 209	Jacket Water Supply Temp. to Main HX · (°C)
TE 210	Jacket Water Discharge Temp. from Main HX (°C)
TE 211	H.W. Return Temp. from GNWT Bldgs. (°C)
TE 212	H.W. Return Temp. from WTP (°C)
TE 213	H.W. Supply Temp. to GNWT Bldgs. & WTP (°C)
TE 214	Outdoor Air Temp. (°C)
TE 215	Jacket Water Return Temp. (°C) from Sutton & Aux. Rads.
FE 405(A1)	DG #1 - Exh. Gas Flow Vel. (ΔP)
FE 406(A2)	DG #2 Exhaust Gas Flow Vel. (ΔP)
FE 407(U1)	Jacket Water Flow Vel. to DG #1 (ft/sec.)
FE 408(U2)	Jacket Water Flow Vel. to DG #3 (ft/sec)
FE 410(A4)	Jacket Water Discharge Flow By-Pass Vel. (ΔP)
FE 411(A3)	H.W. Return Flow Vel. from GNWT Bldgs. (ΔP)
FE 412(U3)	H.W. Return Flow Velocity from WTP (ft/sec)
KW 401	DG #1 Electrical Output (kW)
KW 402	DG #1 Totalized Elect. Output (mW)
KW 403	DG #2 Electrical Output (kW)
KW 404	DG #2 Electrical Output (mW)

DILLON

RESIDUAL HEAT RECOVERY SYSTEM
MONITORING POINTS LOCATION

CAMBRIDGE BAY

FIG No.
5

CAMBRIDGE BAY, JAN. 31, 1985

JACKET WATER TEMPERATURE VS TIME (DG 2)

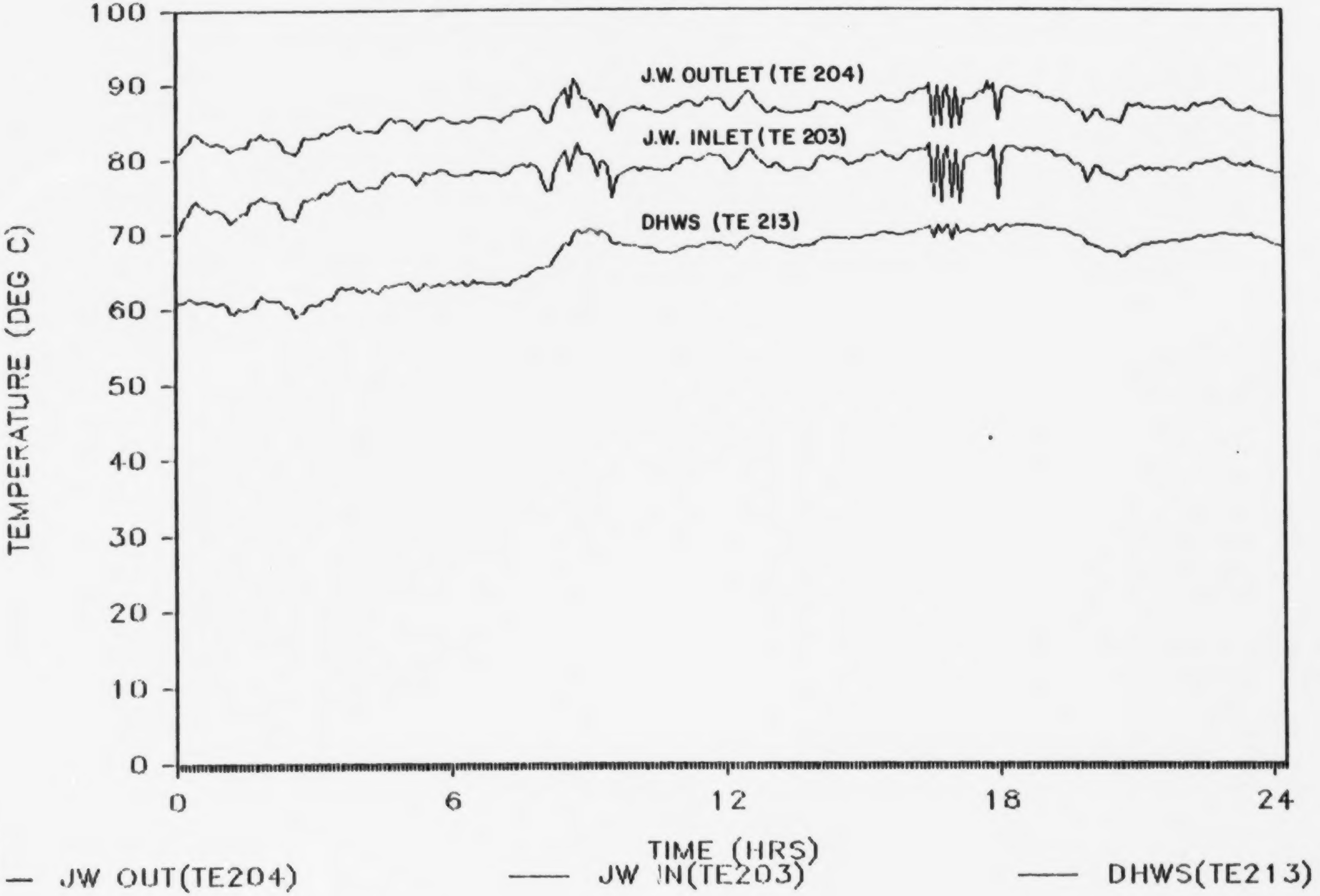


FIG. No.
6

typical day indicates that the heat exchanger (HX) and the radiator are both operating effectively in maintaining the JW inlet temperature in the range of 74 to 80°C. (Manufacturer's recommended range is 74 to 90°C.)

A plot of the temperature rise in the JW, presented in Figure 7, shows that it ranges from 7 to 10°C depending on the electrical load. The trend is as expected, because the amount of heat rejected to the JW (and, at constant water flow rate in the JW loop, the temperature) rise varies directly with the electrical load.

Two operating characteristics are of interest:

- the ratio of temperature rise to load is inversely proportional to load, which is explained by lesser engine efficiencies at lower loads

- mean rise across the DG is greater than the manufacturer's specified 8.3°C at 100 percent load which may be partly attributed to JW flow restriction caused by the recovery HX and pipework

b) Exhaust Gas System

To determine the residual heat which could potentially be recovered from the exhaust gas (EXG) stream at varying loads, the stack temperature relative to electrical output was monitored. Figure 8 represents a typical day and shows how the stack temperature fluctuates relative to load, ranging from 300 to 400°C. The graph shows that there is a direct relationship between stack temperatures and electrical load.

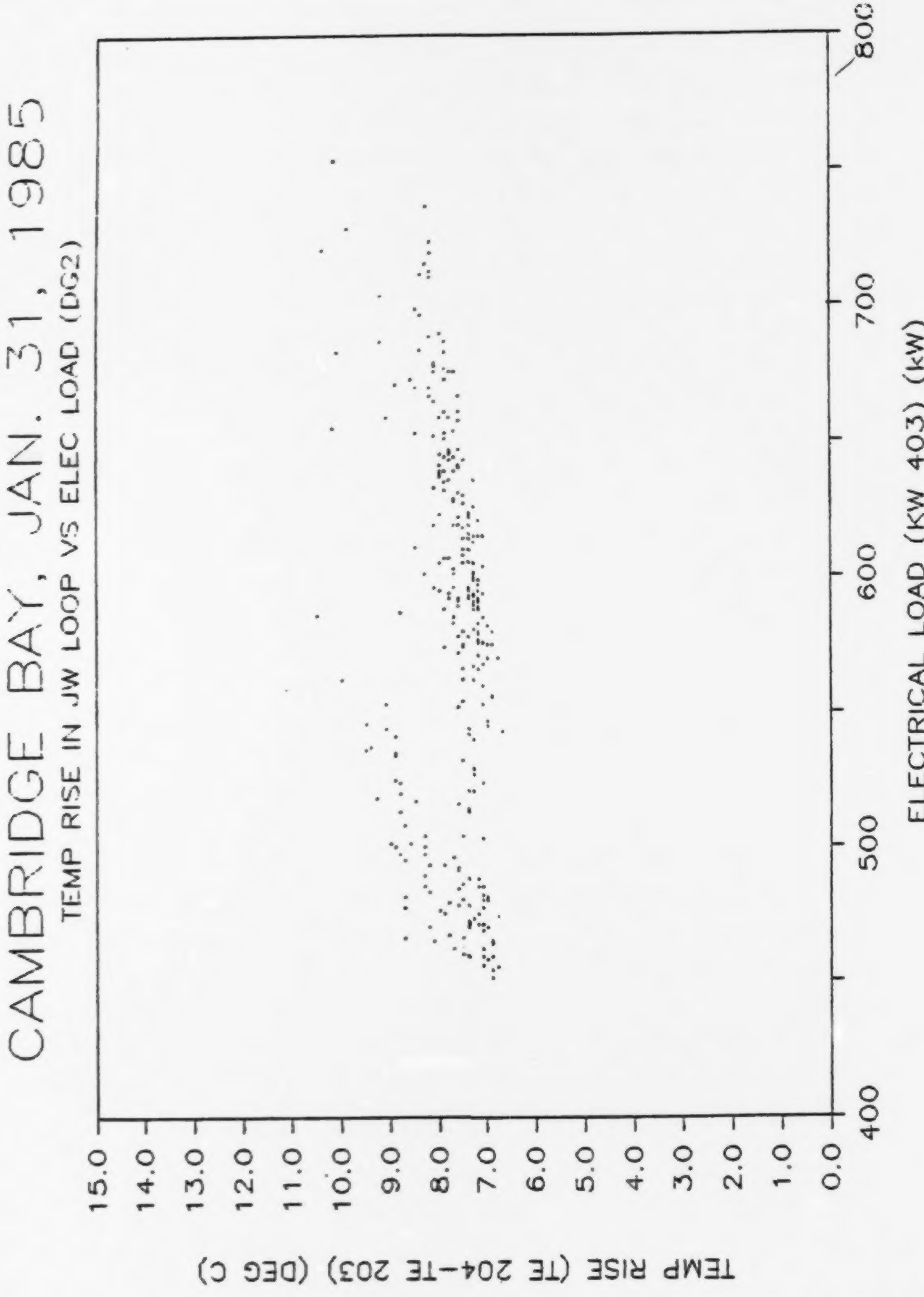

CAMBRIDGE BAY, JAN. 31, 1985
TEMP RISE IN JW LOOP VS ELEC LOAD (DG2)
TEMP RISE (TE 204–TE 203) (DEG C)
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
400
500
600
700
800
ELECTRICAL LOAD (KW 403) (kW)

FIG. No.
7

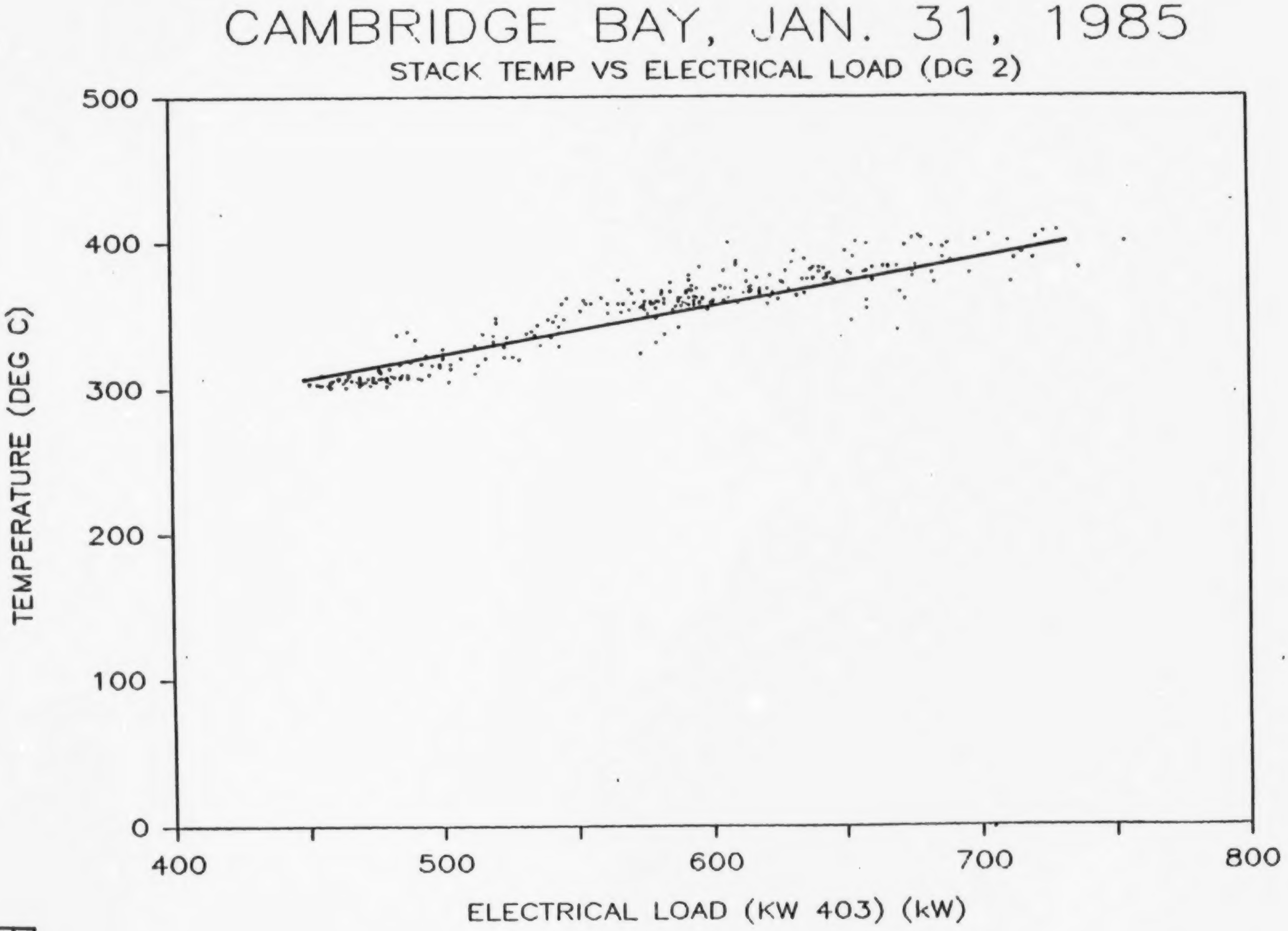

CAMBRIDGE BAY, JAN. 31, 1985
STACK TEMP VS ELECTRICAL LOAD (DG 2)
TEMPERATURE (DEG C)
500
400
300
200
100
0
400
500
600
700
800
ELECTRICAL LOAD (KW 403) (kW)

FIG. No.
8

If the curve is extrapolated to 100 percent load, the expected EXG temperature appears somewhat less than the manufacturer's specified temperature of 475°C. However, the manufacturer bases his temperatures on the turbocharger exhaust, whereas the study data is obtained from the larger--diameter stack and the lower temperatures can be fully explained by thermodynamic expansion.

c) District Hot Water System

Heat from the JW is transferred to the district hot water (DHW) loop by the main heat exchanger (HX). Figure 9 shows the temperature difference between the JW inlet temperature and the district hot water supply (DHWS) outlet temperature from the HX relative to the electrical load. This "approach" (difference between hot side inlet and cold side discharge temperatures) ranges from 15°C to 22°C with an average of approximately 19°C, and the DHWS temperature ranges from 60 to 70°C.

Heat utilization in the GNWT workshops/storage buildings is dependent upon the settings of individual boiler aquastats (see Figure 2). The DHWS loop was too cool during the monitoring period to maintain desired space temperature, and the boilers were operated intermittently to supplement the heat.

At the water treatment plant (WTP) heat from the DHW loop was not used when the DHWS temperature was below the control temperature of 71°C. Figure 9 indicates that even though residual heat was available, very little could be used by WTP because the supply temperature was consistently below the set control point.

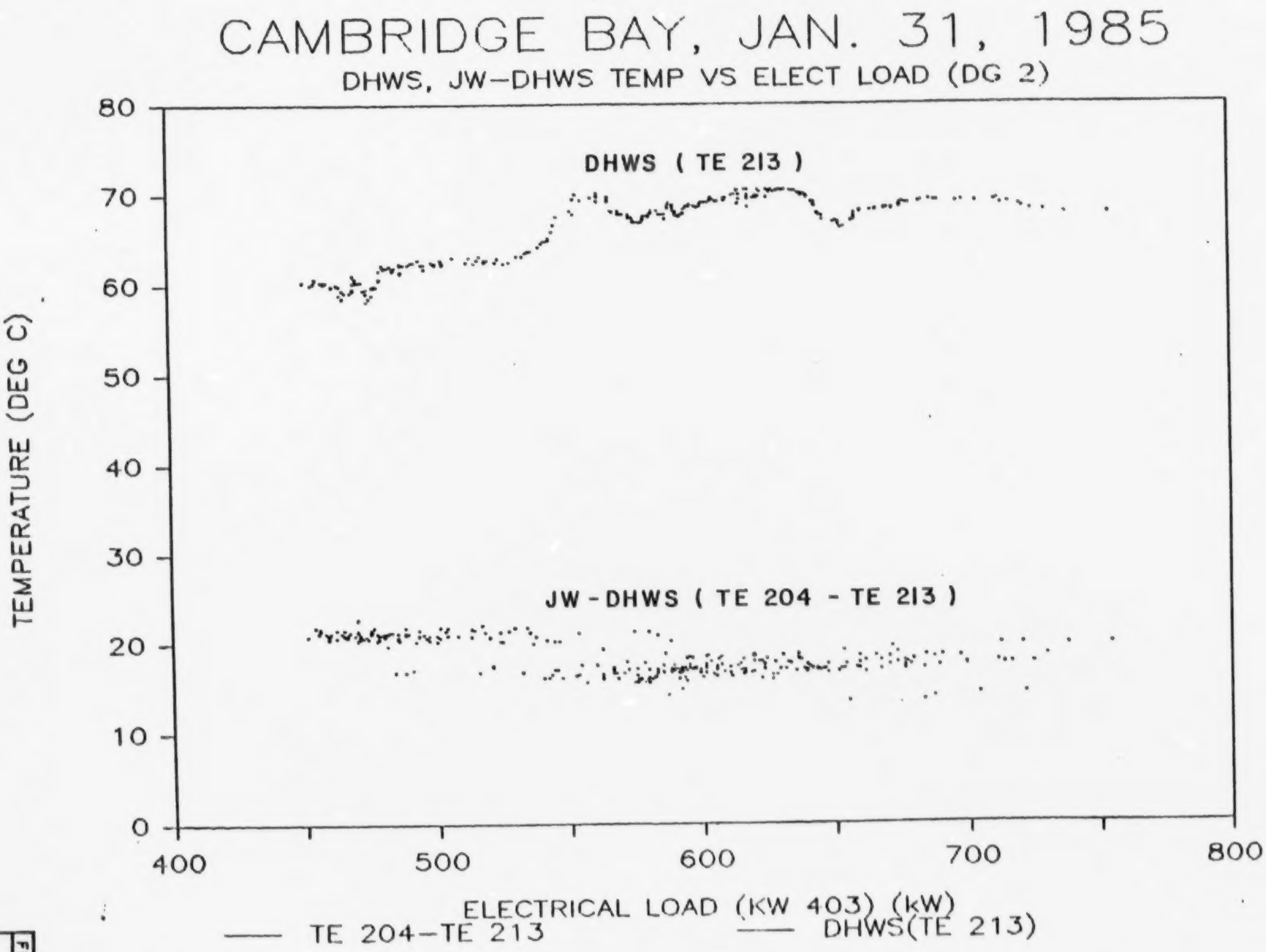

CAMBRIDGE BAY, JAN. 31, 1985
DHWS, JW–DHWS TEMP VS ELECT LOAD (DG 2)
DHWS (TE 213)
JW - DHWS (TE 204 - TE 213)
TEMPERATURE (DEG C)
80
70
60
50
40
30
20
10
0
400
500
600
700
800
ELECTRICAL LOAD (KW 403) (kW)
TE 204–TE 213
DHWS(TE 213)

FIG. No.
9

d) Electric Load Characteristics

Figure 10 shows how the electrical load varies throughout a typical day. Superimposed on this graph is NCPC forecast load (equal to NCPC load factor x peak load). Note that whereas the forecast load for the 1984-85 year was 555 kW, the recorded fluctuation for a typical day (31 January 1985) ranged from a high of 758 kW to a low of 451 kW with a weighted average daily load of 580 kW. (The actual peak and average daily loads for 1984 were 960 and 578 kW respectively.)

To illustrate how the electrical load varied from day to day, Figure 11 was prepared to show average daily electrical load versus time for the period of 19-31 January 1985, inclusive. From this graph, it is evident that the average daily electrical load remained relatively constant and averaged 550 kW throughout this extended period.

e) Jacket Water Heat Recovery Versus Electrical Load

Figure 12 shows that for a typical day, the JW heat available relative to the electrical load ranges from 0.9 to 1.4 kW heat energy per kW of electrical load with the higher values at lower loads (reflecting an inverse relationship between engine efficiency and load). The daily average JW heat, as plotted on Figure 13, is relatively constant at 1.1 kW/kW at 60 to 80 percent of full load. This average output is approximately 18 percent higher than the manufacturer's rated output of 0.93 kW per kW of electrical load at 100 percent load.

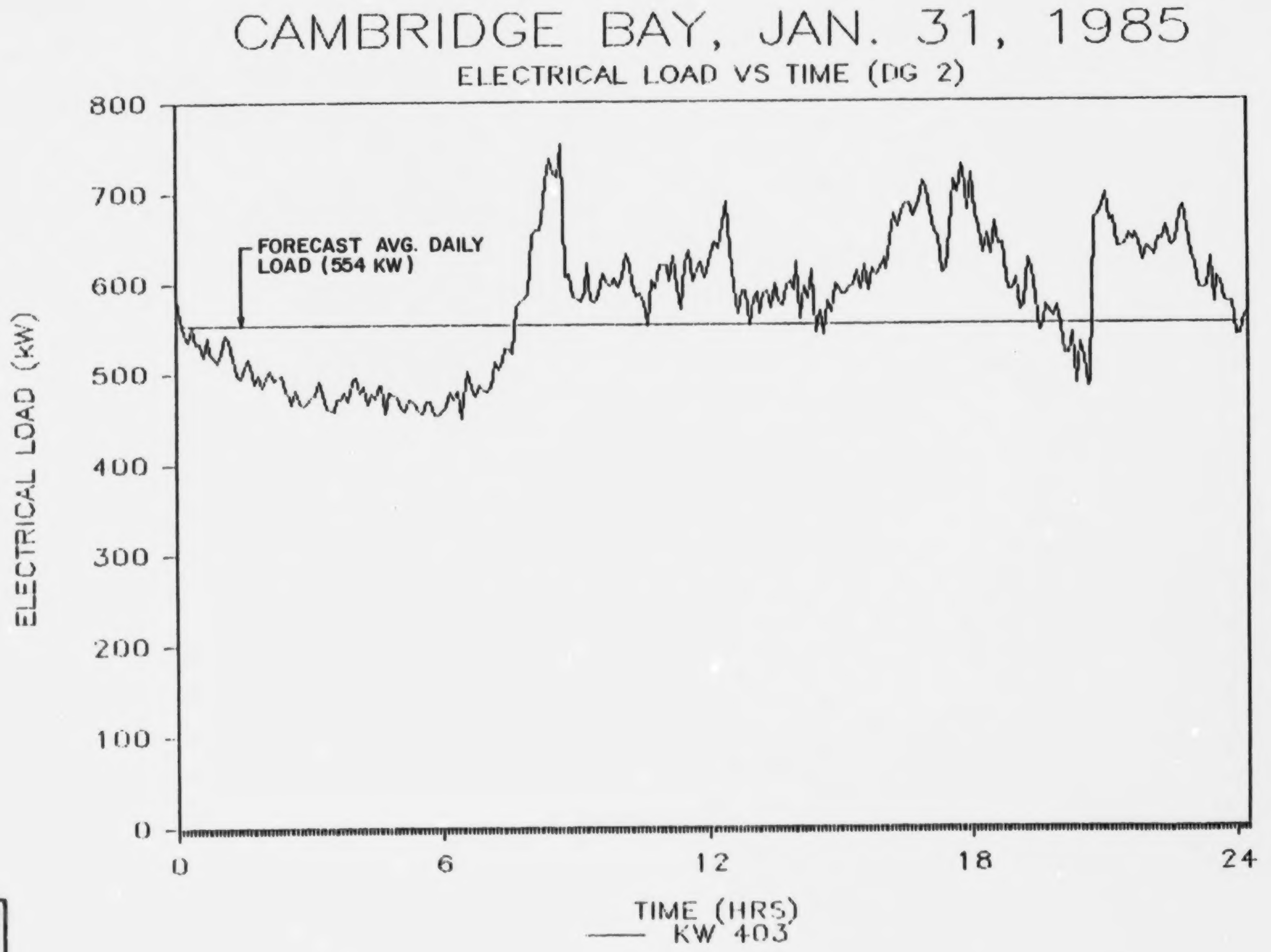

CAMBRIDGE BAY, JAN. 31, 1985
ELECTRICAL LOAD VS TIME (DG 2)
ELECTRICAL LOAD (kW)
800
700
600
500
400
300
200
100
0
FORECAST AVG. DAILY
LOAD (554 KW)
0
6
12
18
24
TIME (HRS)
KW 403

FIG. No.
10

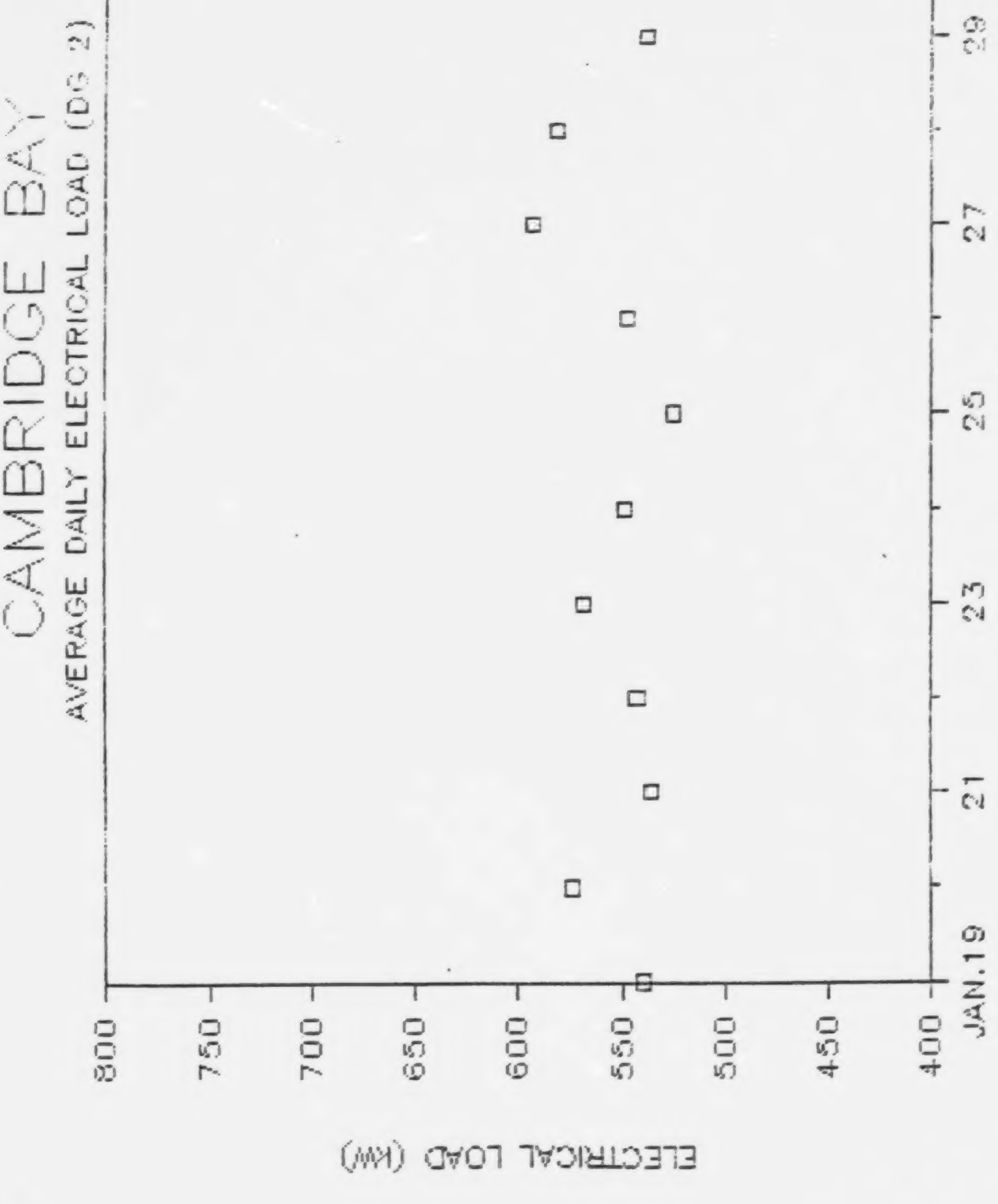

CAMBRIDGE BAY
AVERAGE DAILY ELECTRICAL LOAD (DG 2)
ELECTRICAL LOAD (kW)
800
750
700
650
600
550
500
450
400
DATE
JAN.19
21
23
25
27
29
31

FIG. No.
11

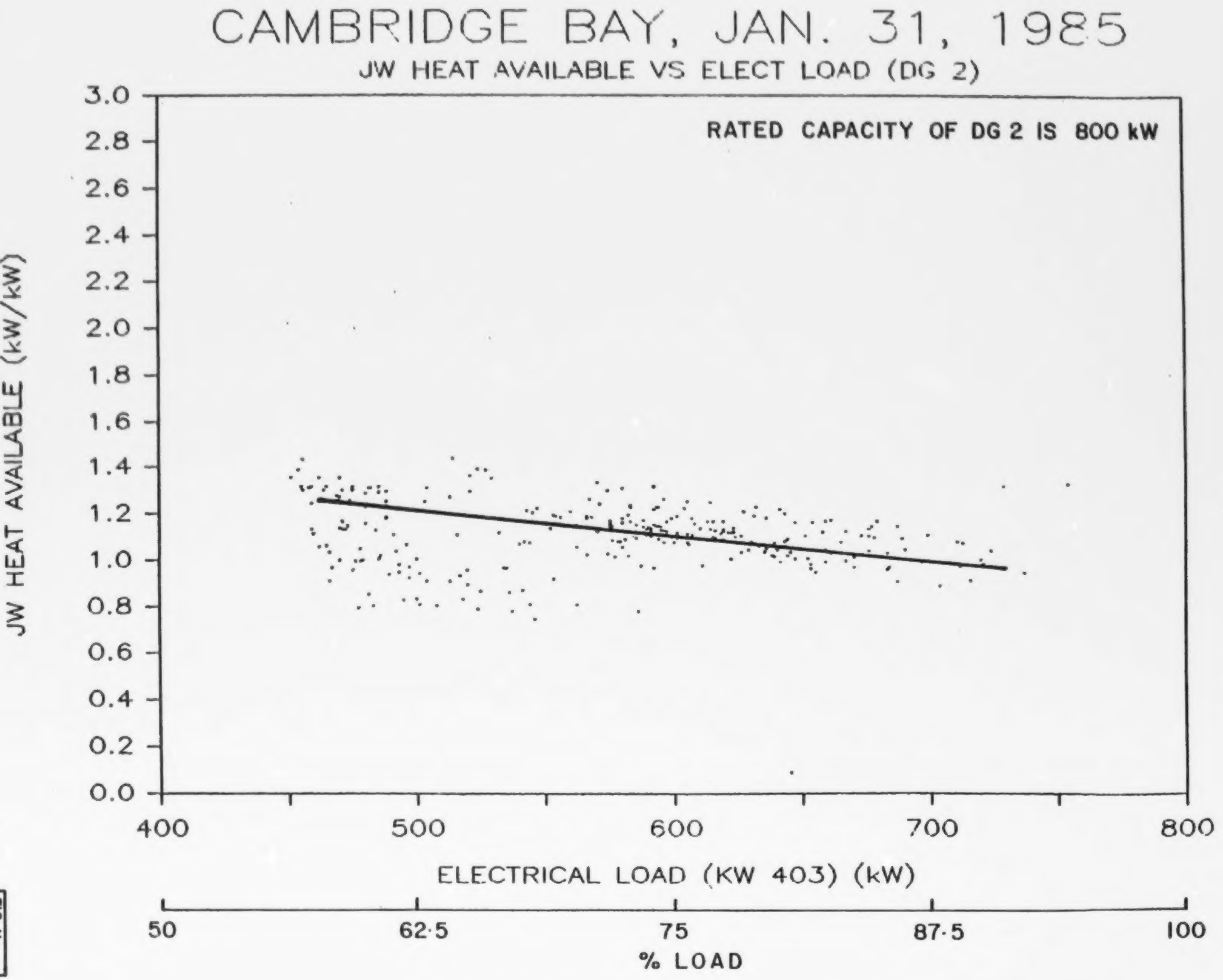

CAMBRIDGE BAY, JAN. 31, 1985
JW HEAT AVAILABLE VS ELECT LOAD (DG 2)
RATED CAPACITY OF DG 2 IS 800 kW
JW HEAT AVAILABLE (kW/kW)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
800
ELECTRICAL LOAD (KW 403) (kW)
50
62·5
75
87·5
100
% LOAD

FIG. No.
12

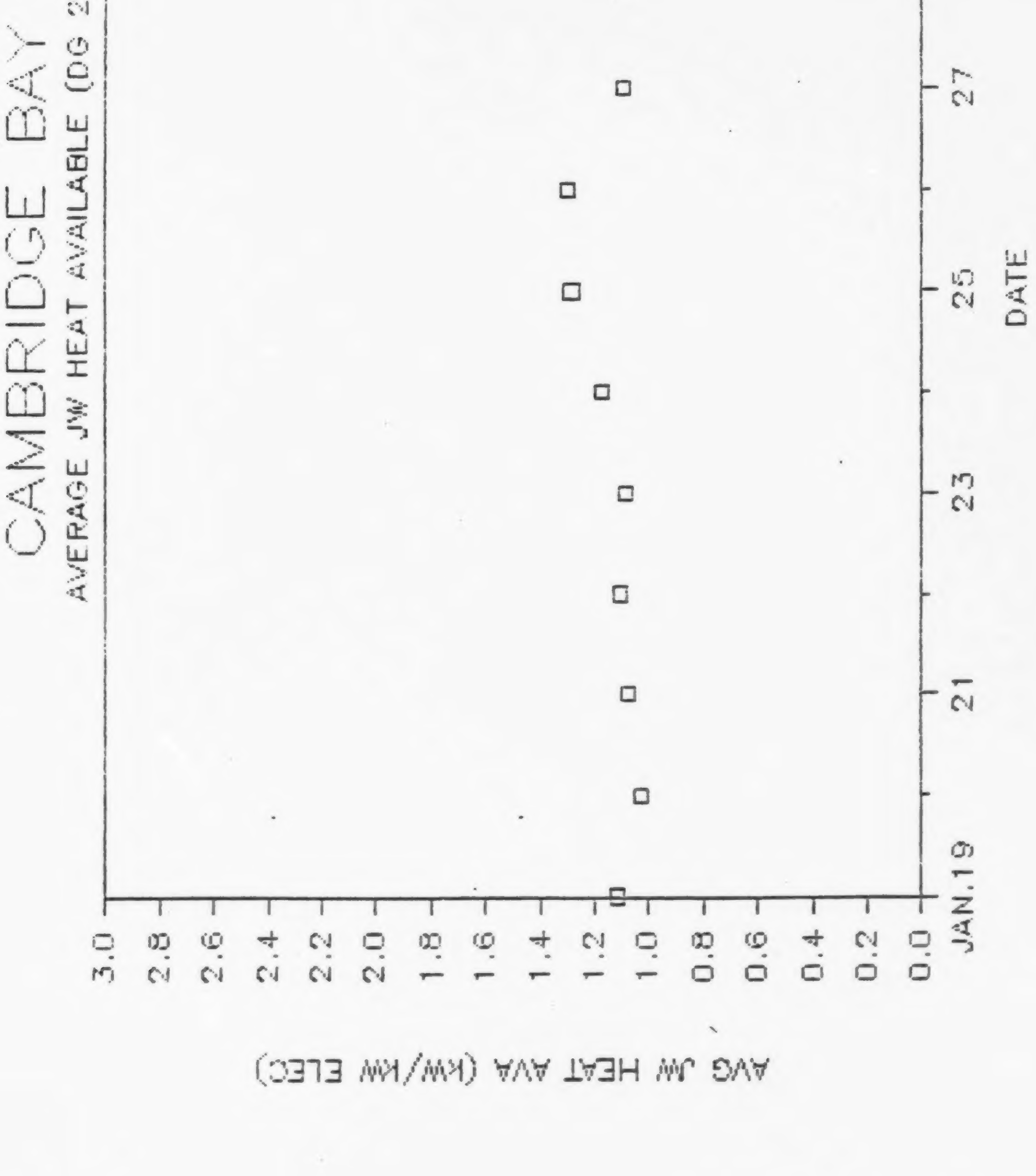

CAMBRIDGE BAY
AVERAGE J/W HEAT AVAILABLE (DG 2)
AVG JW HEAT AVA (KW/KW ELEC)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
JAN.19
21
23
25
27
29
31
DATE

FIG. No.
13

The inverse relationship of engine efficiency to load is demonstrated by the theoretical heat balance for a diesel engine given in Table 3. Note that the values quoted elsewhere differ from the manufacturer's figures in this report, and are presented simply to demonstrate typical relationships.

TABLE 3

TYPICAL HEAT BALANCE OF DIESEL ENGINE

Percent Load	Shaft Power	Engine Jacket Oil Cooler Aftercooler	Exhaust Gases	Direct Losses (Radiation)
100	33	30	32	5
75	32	32	30	6
50	28	36	29	7
25	25	40	27	8

Source: Bibliography Ref. 11.

f) Utilization of Jacket Water Heat

Figure 14 represents a typical day's utilization of the available JW heat by both the WTP and connected GNWT buildings. Normal utilization rates vary from 30 to 45 percent with extreme values of 20 and 50 percent.

Figure 15 indicates that the percentage utilization increased as the DHWS temperature increased, as would be expected considering the user building control modes.

The data as plotted on Figure 16 indicates that on the longer term average, only about 45 percent of the JW heat available was utilized.

CAMBRIDGE BAY, JAN. 31, 1985

PERCENT JW UTILIZED VS TIME (DG 2)

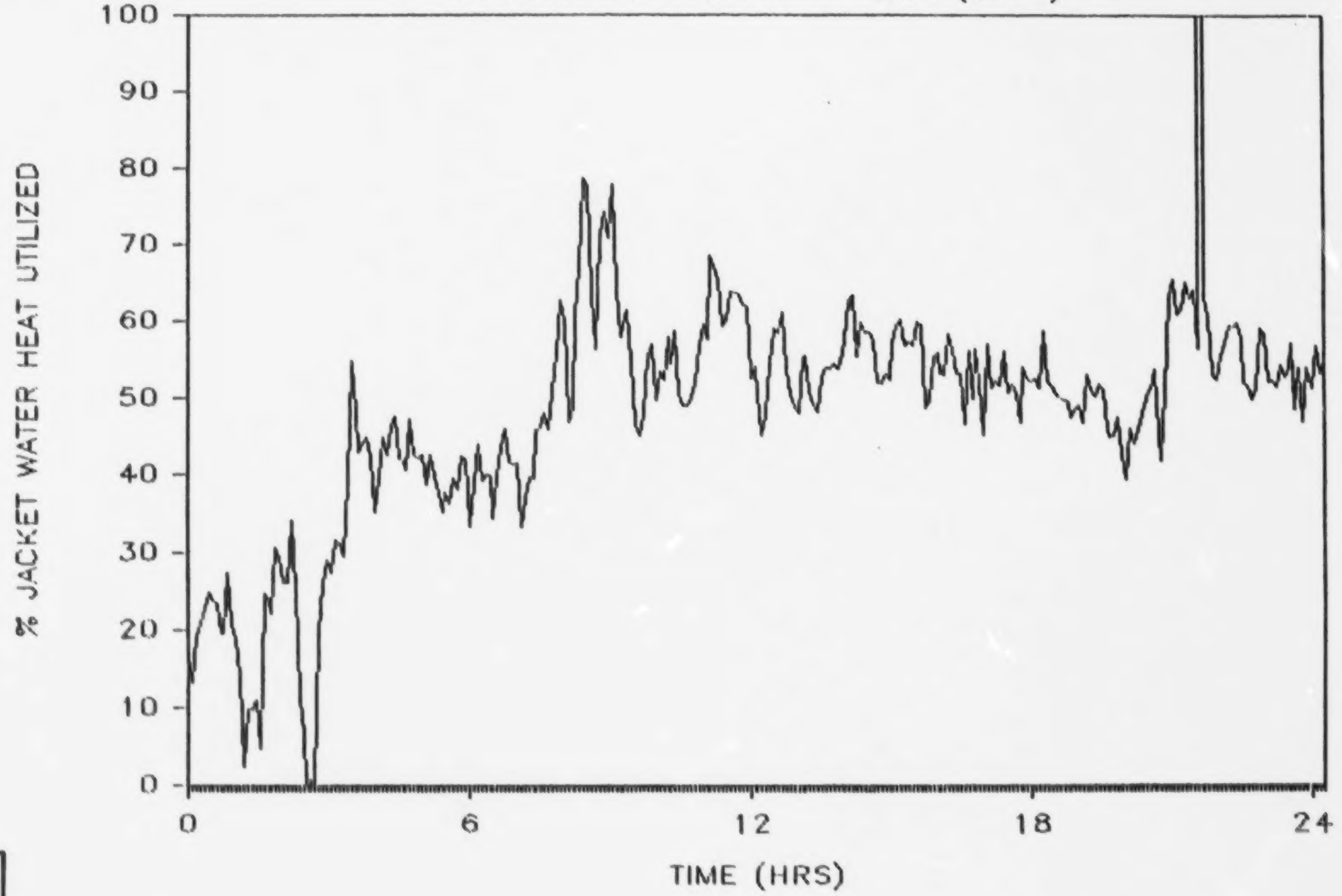


FIG. No.
14

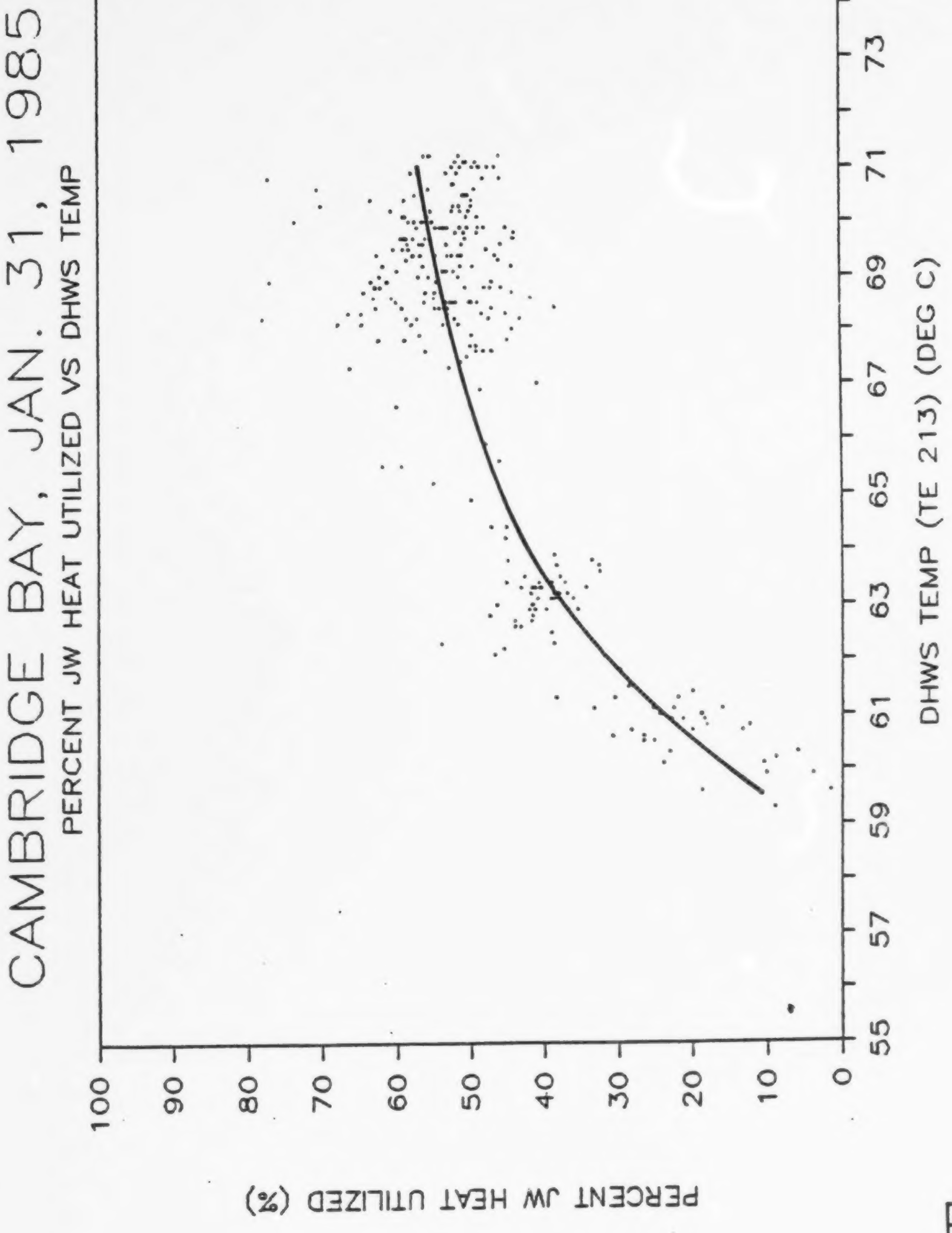
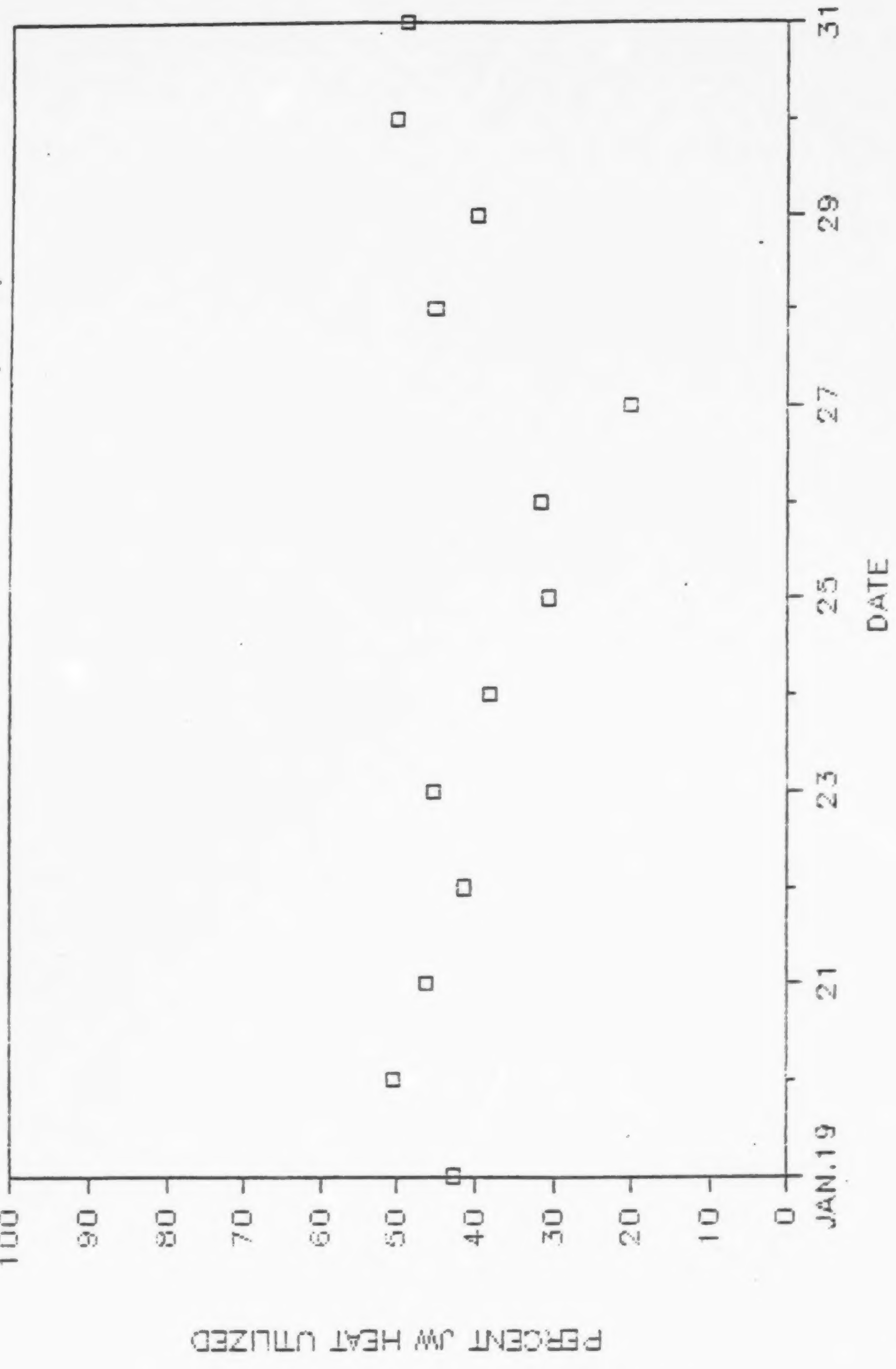

CAMBRIDGE BAY, JAN. 31, 1985
PERCENT JW HEAT UTILIZED VS DHWS TEMP
PERCENT JW HEAT UTILIZED (%)
100
90
80
70
60
50
40
30
20
10
0
55
57
59
61
63
65
67
69
71
73
75
DHWS TEMP (TE 213) (DEG C)

FIG. No.
15



CAMBRIDGE BAY

AVG PERCENT JW HEAT UTILIZED (DG 2)

FIG. No.

16

g) Exhaust Gas Heat Available

Figure 17 is a plot of the calculated value of the EXG heat available for a typical day (31 January 1985), based on maintaining a constant outlet gas temperature of 176°C from an exhaust gas heat recovery silencer (EHRS). The ratio varies from 0.55 to 0.80 kW of heat per kW of electrical energy in direct proportion to the load. The consistency in the average daily ratio of recoverable exhaust heat to electrical energy over an extended period is evident from Figure 18. The calculated values over the monitored period indicate that 0.65 to 0.7 kW of heat energy can be recovered from exhaust gases for each kW of electrical energy.

Note that the total heat in the exhaust stream is significantly higher (typically 60%) than the calculated available value. The recovery ratio could be increased by lowering the gas discharge temperature closer to or below the dew point, which would necessitate a corrosion-resistant stainless steel EHRS and stack.

According to manufacturer's specifications, the expected available heat from a EHRS, based on 100 percent load and 475°C inlet gas temperature, should be approximately 1.00 kW per kW of electrical load. The typical heat balance for a diesel generator (DG) unit shows that the ratio of EXG heat to electrical output decreases as the load decreases. Correcting for the residual heat left in the EXG stream would bring the calculated recovery rate in line with the theoretically expected ratio at reduced load.

CAMBRIDGE BAY, JAN. 31, 1985

EXH HEAT AVA PER kW ELEC LOAD (DG 2)

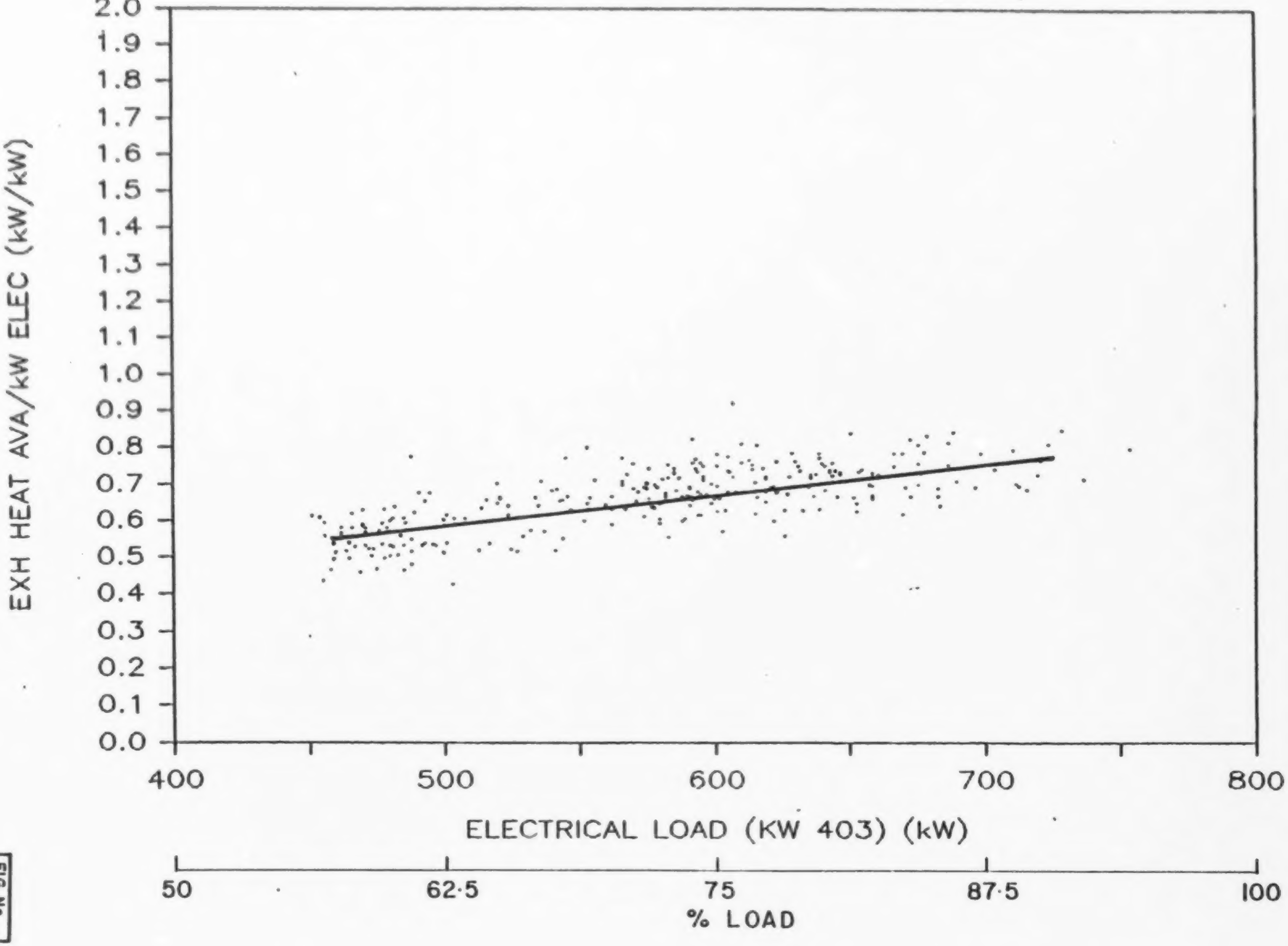


FIG. No.
17

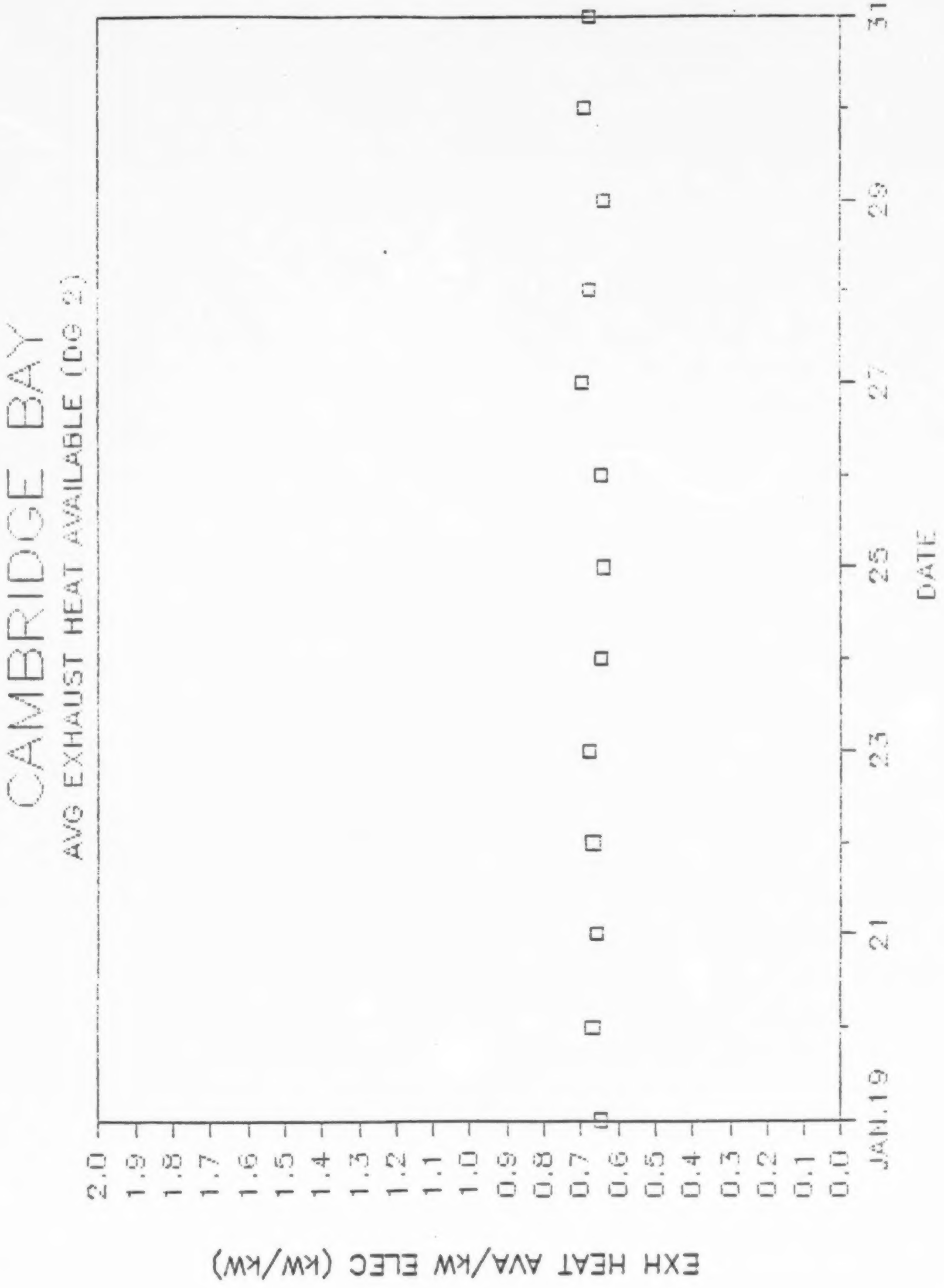

CAMBRIDGE BAY
AVG EXHAUST HEAT AVAILABLE (DG 2)
EXH HEAT AVA/kW ELEC (kW/kW)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
JAN.19
21
23
25
27
29
31
DATE

FIG. No.
18

h) Fuel Consumption

Fuel consumption for DG1 and DG2 is metered, and recorded on a daily basis by NCPC's operating staff. (The two other Lister-Blackstone gen-sets in the plant, which are not connected to the heat recovery system and are therefore not included in this study, are separately metered.)

NCPC recorded 34 068 litres (L) of fuel consumed by DG1 and DG2 for 19-31 January 1985, inclusive. Generation for the same period by these units, recorded on the Data Logger, totalled 174 MW·h. The marine diesel fuel used by NCPC at Cambridge Bay has a quoted heating value of 10.6 kW·h/L (164 400 BTU/Ig), which indicates an impossibly high thermal efficiency of 48%. Generation figures can be shown to agree with NCPC's own records, and the error must therefore derive from fuel meter readings.

By subtracting the daily Data Logger generation values from the plant totals, generation values are obtained for the Blackstone units. Using the available metered fuel values for these units, a thermal efficiency of 33% is obtained. This value is as expected, and it may therefore be deduced, tentatively, that the erroneous fuel records originate not with the Blackstones but in the metering of DG1 and DG2.

NCPC's daily log shows a plant consumption of 99 146 L for 1-31 January 1985, and total generation of 475 MW·h. These values, which include the Blackstone units, give an overall efficiency of 45%. A separate record is maintained by NCPC on a monthly basis, with fuel consumption obtained by dipping the fuel tanks. For the month of January 1985, this record shows 134 192 L for a total generation of 470 MW·h, giving a more reasonable thermal efficiency of 33%.

By applying the ratio of 134 192 : 99 146 to the total fuel use from the daily log, and by subtracting the Blackstone values (as logged) from the amended daily total, an adjusted value for DG1 and DG2 was obtained.

Adjusted values were then compared with theoretical fuel consumptions obtained by imposing daily generation on Caterpillar's characteristic curves for the D399. Results, which are summarized in Table 4, show agreement within 5% between the adjusted study data and the theoretical. This is taken as confirmation that the assumptions noted above were valid, and that adjusted fuel consumptions for DG1 and DG2 may be used with confidence.

TABLE 4

CAMBRIDGE BAY FUEL CONSUMPTION

	Fuel Consumption (L)			Electrical Output kW·h
Date	Reported[1]	Adjusted	Estimated[2]	
19 Jan	2 359	3 279	3 754	12 943
20 Jan	2 728	3 692	3 953	13 680
21 Jan	2 537	3 694	3 713	12 792
22 Jan	2 682	3 883	3 771	13 008
23 Jan	2 687	3 868	3 934	13 608
24 Jan	2 678	3 881	3 796	13 100
25 Jan	2 541	3 673	3 688	12 696
26 Jan	2 037	2 896	3 797	13 104
27 Jan	3 010	4 073	4 111	14 256
28 Jan	2 796	4 030	4 029	13 956
29 Jan	2 455	3 723	3 745	12 910
30 Jan	2 719	3 916	4 071	14 112
31 Jan	2 841	4 043	3 997	13 838
TOTALS	34 068	48 650	50 359	174 003

Note: 1. "Reported" data are taken from NCPC Cambridge Bay Plant daily log sheets and record consumption of Esso Marine diesel fuel, with a heating value of 10.6 kW·h/L (164 400 Btu/Ig).

2. "Estimated" data are from Caterpillar characteristics, which are based on diesel fuel with a heating value of 10.7 kW·h/L (166 481 Btu/Ig).

i) Theoretical Versus Actual Residual Heat Generation

Figure 19 shows the theoretical energy output per unit of energy input for a diesel generator at 100 percent load (based on manufacturers' data). This typical unit might be expected to convert approximately 32 percent to electrical energy, 30 percent to heat energy in the jacket water, 29 percent to exhaust gas heat energy, with the remaining 9 percent going to radiant energy and miscellaneous losses.

TYPICAL DIESEL GENERATOR
EXPECTED ENERGY DISTRIBUTION @ 100% LOAD

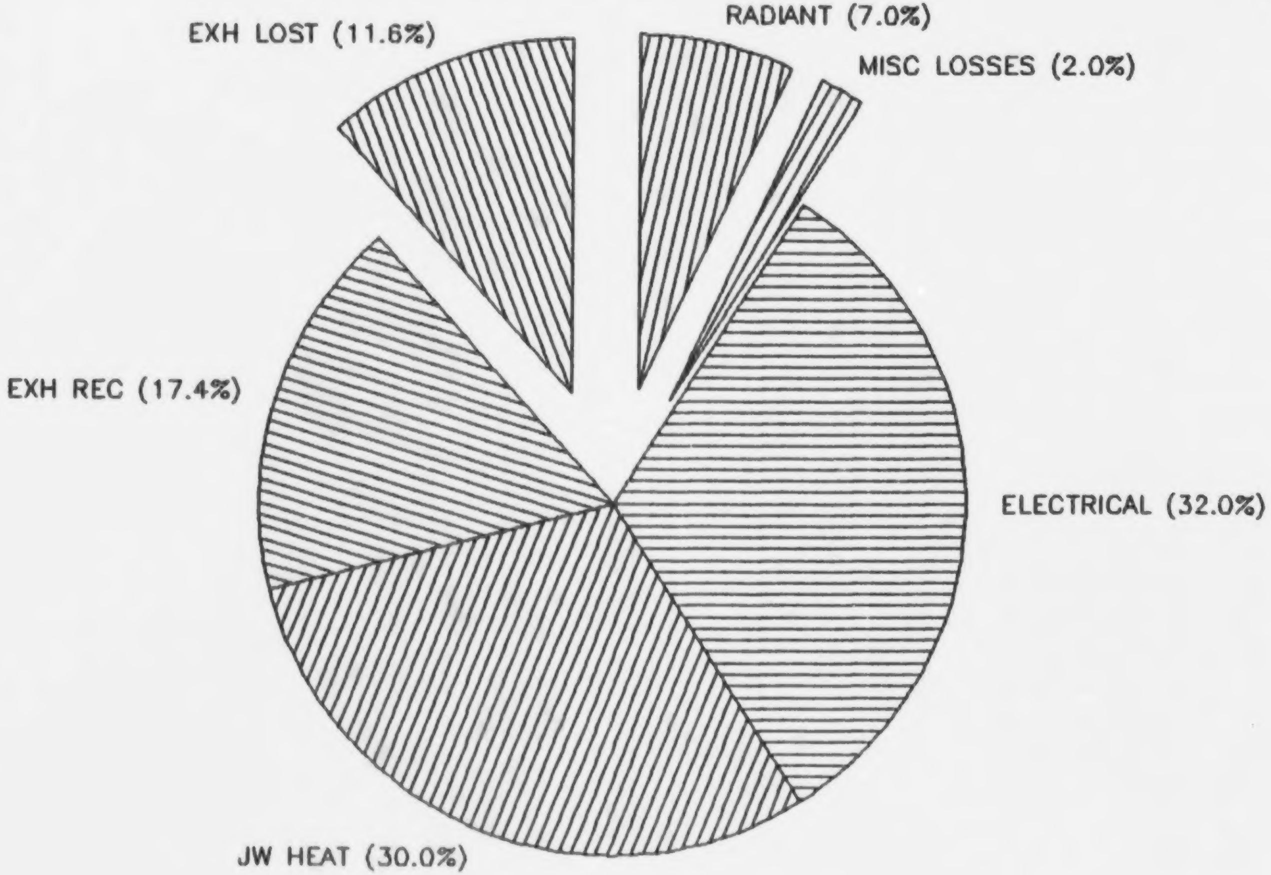


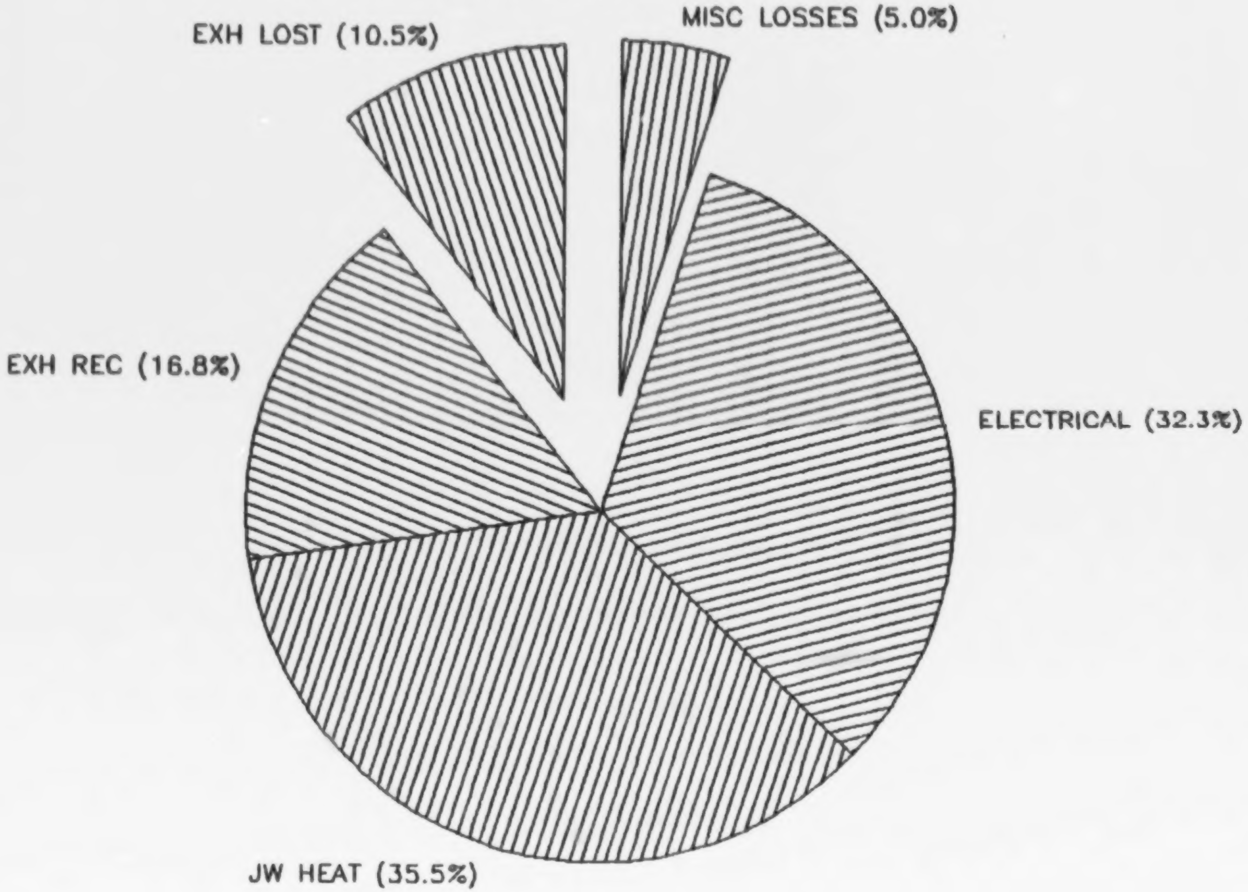
FIG. No.
19

The energy utilization achieved at Cambridge Bay over a typical day was compared with these theoretical values. Because the daily totals of electrical, jacket, and exhaust energy (576 kW, 634 kW, and 731 kW, respectively) exceeded the fuel input energy (1786 kW), it was necessary to adjust some or all of the values. In order to properly redistribute the values, the following logical evaluation of the data was undertaken:

- Electrical conversion is based on firm, verified data;
- Jacket water heat calculations gave consistent results both in the primary circuit and (through heat balance) on the related secondary side of the heat exchanger, and may therefore be quoted with some confidence;
- Exhaust flows are on the average about 50% higher than the manufacturer's value - exhaust heat is the most questionable parameter of the three.

It was therefore postulated that exhaust heat may be reduced by 38 percent, to correspond more closely with manufacturer's data. This results in miscellaneous losses of 5 percent which, considering that the Cambridge Bay diesels operate at cooler temperatures than the manufacturer's standard, is a reasonable value. The resultant distribution is presented in Figure 20.

While it is appreciated that other comparisons contained in this report are affected by these same considerations, it may be noted that confidence limits on the suspect parameter are within 20 percent, and do not invalidate the conclusions reached.



CAMBRIDGE BAY, JAN. 31 1985
ESTIMATED ENERGY DISTRIBUTION @ 72 % LOAD

FIG No.
20

4.3 Lac La Martre

4.3.1 Installation and Operation of Monitoring Equipment

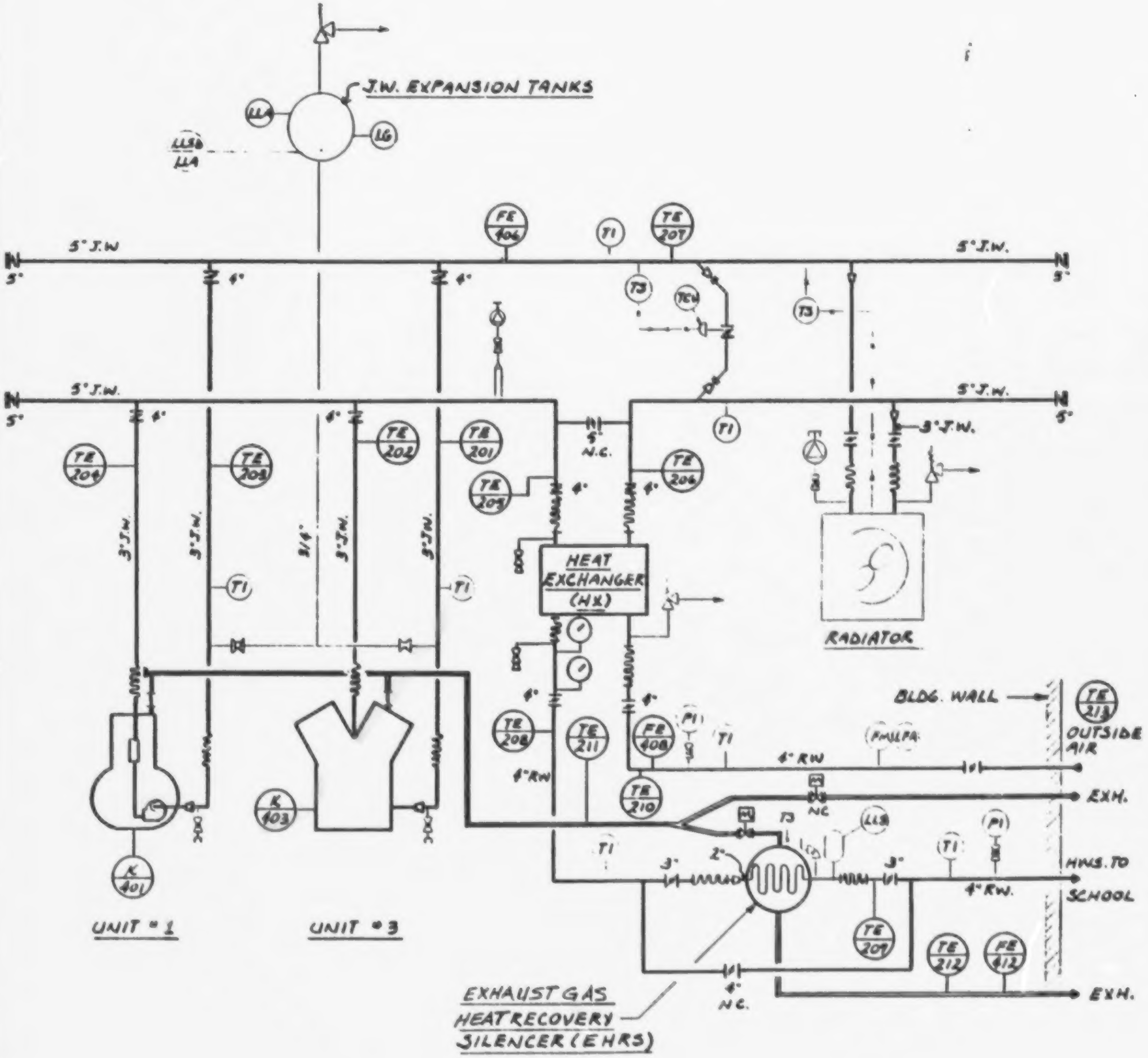
The monitoring equipment at Lac La Martre was installed and set up in the same manner as for Cambridge Bay. The monitoring points established in the NCPC plant are shown schematically on Figure 21.

Existing "Annubar" elements for liquid flow (FE 406 and FE 408) were found to be for 3" pipe, undersized for the pipes in which they were installed (5" and 4" respectively). Readings proved to be erratic, and design flow rates were therefore adopted for purposes of analysis.

Gas flow (FE 412) was obtained by installing an "Annubar" through an existing threaded fitting in the EXG piping downstream of the EHRS. Problems arose with this data point because of plugging of the ports on this sensor with soot (which is believed to come from deposits within the silencer and/or abnormal operation of the diesels). The readings showed considerable fluctuation, and reversals from positive to negative values, and could not be used for analytical purposes. It was necessary to adopt the manufacturer's standard EXG flows (which are stated to remain fairly constant across the operating range).

Temperature readings from TE 412 (measuring EXG temperature at the EHRS outlet) read considerably lower than an existing pyrometer. It appeared that this latter instrument, which did not vary with changing loads, was stuck at 195°C.

It was hoped to record school boiler operation by connecting


J.W. EXPANSION TANKS
LLA
LG
LLSD
LLA
FE 406
TI
TE 207
5" J.W
5"
4"
4"
5" J.W.
5"
T3
TCV
T3
5" J.W.
5"
5" J.W.
5"
4"
4"
TE 204
TE 203
TE 202
TE 201
5" N.C.
TE 205
4"
4"
TE 206
3" J.W.
3" J.W.
3" J.W.
3/4"
3" J.W.
3" J.W.
TI
TI
HEAT EXCHANGER (HX)
RADIATOR
4"
4"
TE 208
4" RW
TE 211
FE 408
PI
TI
TE 210
4" RW
FMSLPA
BLDG. WALL
TE 213
OUTSIDE AIR
EXH.
NC
T3
LLS
PI
TI
2"
3"
3"
4" RW.
HWS. TO SCHOOL
K 403
K 401
UNIT # 1
UNIT # 3
TE 209
TE 212
FE 412
4" N.C.
EXH.
EXHAUST GAS HEAT RECOVERY SILENCER (EHRS)

LEGEND

TE 201	Jacket Water Supply Temperature (^{o}C) to DG #3
TE 202	Jacket Water Discharge Temperature (^{o}C) from DG #3
TE 203	Jacket Water Supply Temperature (^{o}C) from DG #1
TE 204	Jacket Water Discharge Temperature (^{o}C) from DG #1
TE 205	Jacket Water Supply Temperature to H.X. (^{o}C)
TE 206	Jacket Water Discharge Temperature from H.X. (^{o}C)
TE 207	Total Jacket Weater Supply Temperature to DG Units (^{o}C)
TE 208	R.W. Discharge and E.H.R.S. Water Supply Temperature (^{o}C)
TE 209	R.W. Discharge Temperature from E.H.R.S. (Supply Water to School) (^{o}C)
TE 210	R.W. Supply Water Temperature to H.X. (^{o}C)
TE 211	Exhaust Gas Supply Temperature to E.H.R.S. (^{o}C)
TE 212	Exhaust Gas Discharge Temperature from E.H.R.S. (^{o}C)
TE 213	Outside Temperature (^{o}C)
FE 406	Total J.W. Flow to DG # 1 & 3
FE 408	R.W. Flow to H.X.
FE 412	Exhaust Gas Discharge Flow from E.H.R.S.
K 401	Electrical Output Meter DG #1 (kW)
K 403	Electrical Output Meter DG #3 (kW)

DILLON

RESIDUAL HEAT RECOVERY SYSTEM
MONITORING POINTS LOCATION

LAC LA MARTRE

FIG No
21

relays to the aquastats, which in turn would be connected back to an event-recording channel on the Data Logger. However, this idea was abandoned because snow cover on the school playground was insufficient to provide adequate protection to the connecting wire.

4.3.2 Discussion of Results

a) Jacket Water System

The jacket water (JW) inlet temperature to the diesel generator (DG) units was monitored by Sensors TE 201, 203 and 207. Sensor TE 207 on the common header feeding each DG unit, was installed to verify the temperature data recorded by TE 201 and TE 203 on the individual JW supply pipe to each DG unit.

As was expected, the data from TE 207 and the branch sensor TE 201, plotted on Figure 22 for a typical day, are virtually identical (DG NO. 3 only was operated on this day). Note the fluctuation in the JW inlet temperature (TE 201) which occasionally dips below 70°C. According to the diesel manufacturer, JW inlet temperature should be maintained in the range of 74 to 91°C. Lower temperatures subject the engine to thermal stresses and subsequent premature failure. The temperature dips may be partly attributed to the uncontrolled JW flow through the heat exchanger (HX) which allows the DHW system to extract an uncontrolled amount of heat energy out of the JW loop.

A review of the JW inlet temperature to the HX, as monitored by TE 205, and the DHWS outlet temperature from the HX (TE 208), as plotted for a typical day on Figure 23, shows a

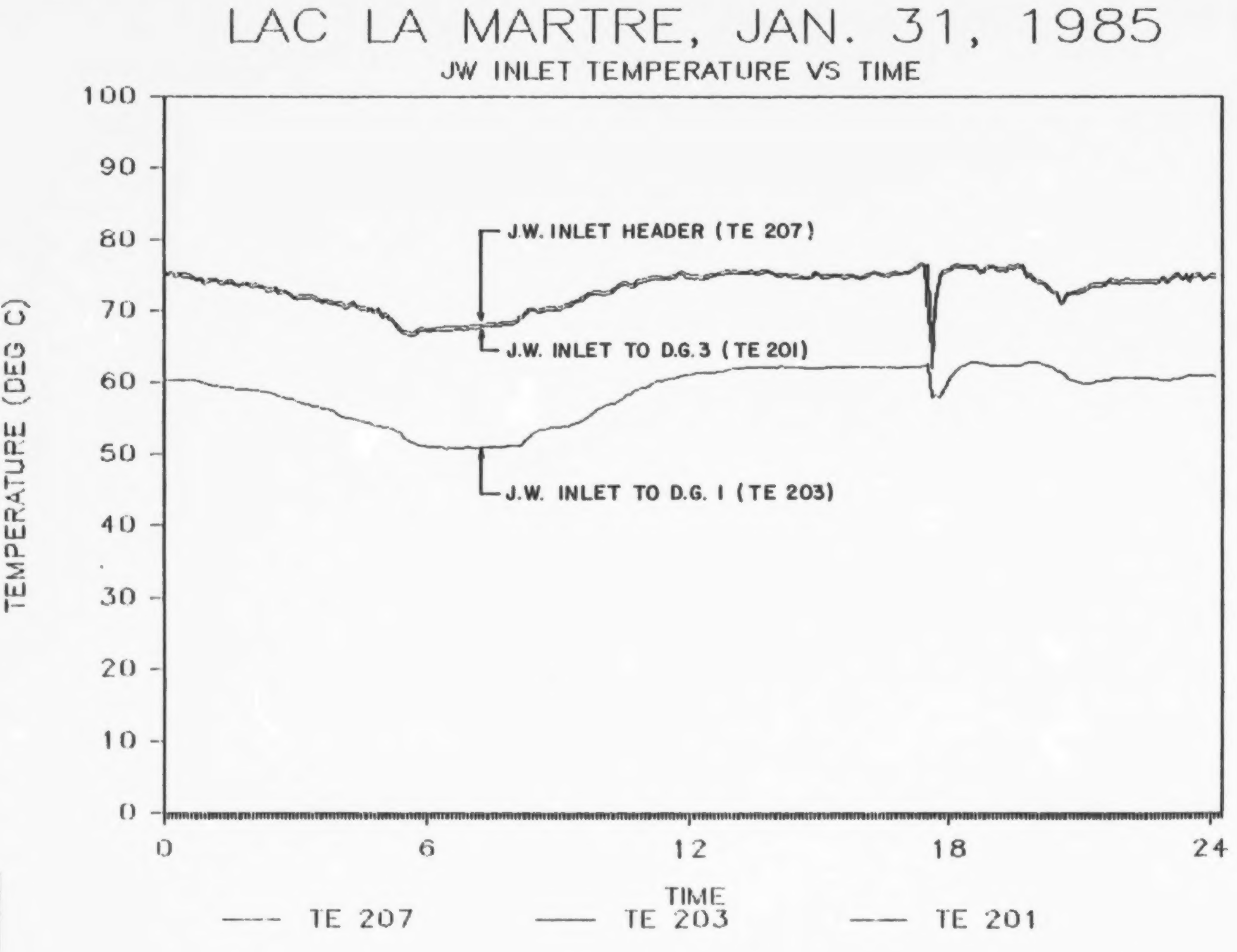

LAC LA MARTRE, JAN. 31, 1985
JW INLET TEMPERATURE VS TIME
TEMPERATURE (DEG C)
100
90
80
70
60
50
40
30
20
10
0
0
6
12
18
24
TIME
J.W. INLET HEADER (TE 207)
J.W. INLET TO D.G.3 (TE 201)
J.W. INLET TO D.G. I (TE 203)
TE 207
TE 203
TE 201

FIG. No.
22

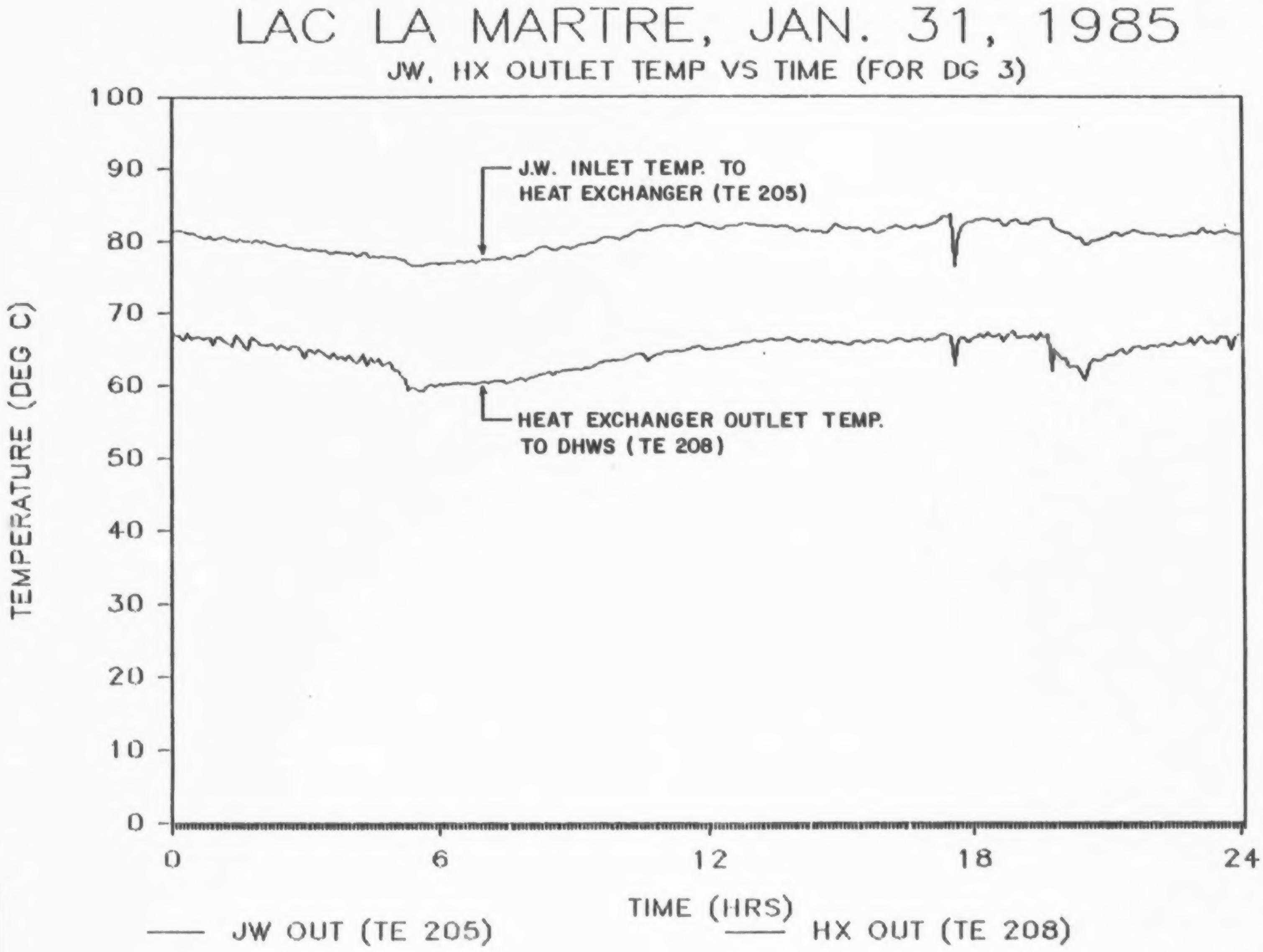

LAC LA MARTRE, JAN. 31, 1985
JW, HX OUTLET TEMP VS TIME (FOR DG 3)
TEMPERATURE (DEG C)
100
90
80
70
60
50
40
30
20
10
0
J.W. INLET TEMP. TO
HEAT EXCHANGER (TE 205)
HEAT EXCHANGER OUTLET TEMP.
TO DHWS (TE 208)
0
6
12
18
24
TIME (HRS)
JW OUT (TE 205)
HX OUT (TE 208)

FIG. No.
23

relatively constant temperature differential of approximately 15°C. While such a large approach allows usage of a smaller HX, it results in a lower DHWS temperature that manifests itself in oversized radiation equipment at the end user facility. Even though the larger radiators can be provided relatively easily and economically in a new facility, similar upgrading would be very difficult and expensive for existing potential residual heat users, especially where space is limited.

The diesel manufacturer designs JW systems for a rise of 8.3°C at 100 percent load. Figure 24 shows the temperature rise (TE 205 - TE 207) for a typical day to range from 6 to 9 degrees. A slight trend to increasing JW temperature as the electrical load increases above 35 percent is apparent. This reflects the expected trend towards higher amounts of heat energy being rejected to the JW as the electrical load increases. Below the 35 percent range, JW temperature increases upon decreasing load. This is due to the effect of engine inefficiency at low load.

Because of problems with existing flow sensor FE 406 (which gave erratic results ranging from 5 to 7 L/s), the manufacturer's specified coolant flow rate of 4.1 L/s (for DG No. 3, with conventional radiator in line) was used as the basis for analysis. The pressure drop across the recovery heat exchanger is expected to be of the same order as a radiator, and the flow is adopted for study purposes.

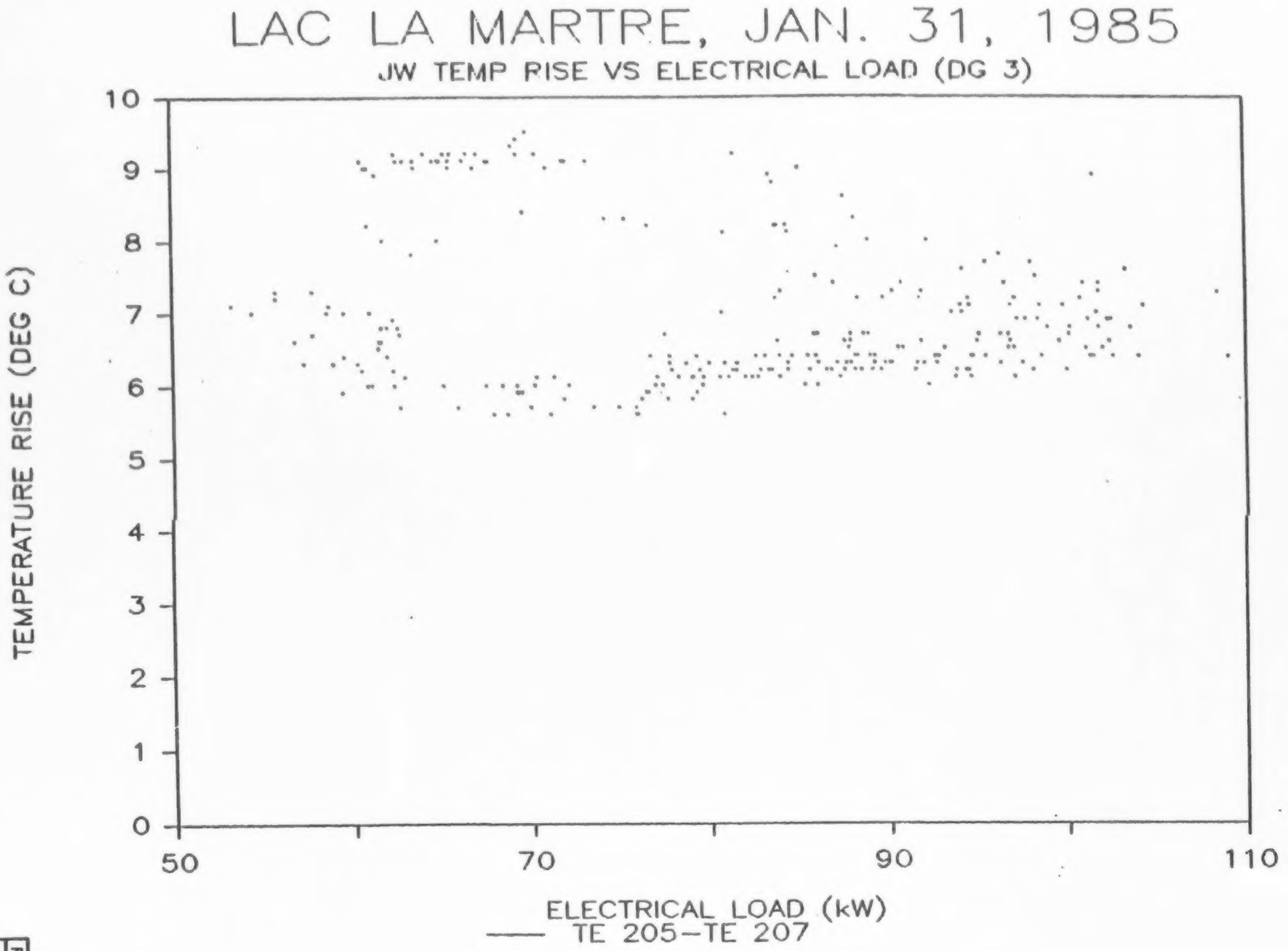

LAC LA MARTRE, JAN. 31, 1985
JW TEMP RISE VS ELECTRICAL LOAD (DG 3)
TEMPERATURE RISE (DEG C)
0
1
2
3
4
5
6
7
8
9
10
50
70
90
110
ELECTRICAL LOAD (kW)
TE 205–TE 207

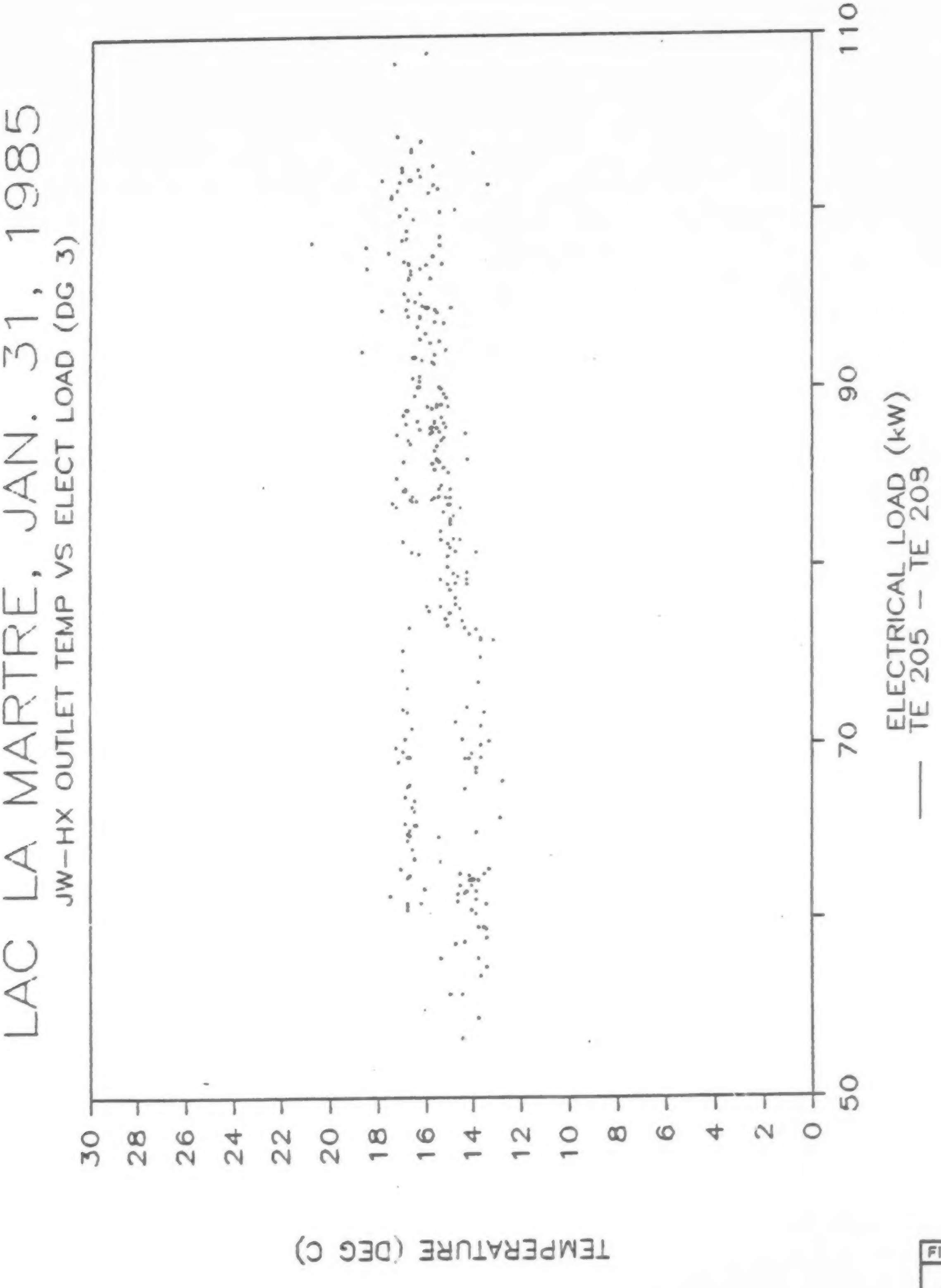
FIG. No. 24

Figure 25 demonstrates the direct relationship between the HX approach (i.e., the difference of the JW inlet and DHWS outlet temperatures) and the electrical output. This indicates that even though the JW inlet temperature to the HX is higher, the amount of heat energy transferred to the DHW loop remains relatively constant; the implication being that the HX is limited in capacity and cannot fully transfer all available JW heat to the DHW loop.

(A review of this HX, details of which are appended under Appendix "C-3", indicates that it was designed for a maximum input of 341 kW in the primary loop (JW inlet) and 331 kW output from the secondary loop (DHWS outlet) at an approach of 15°C. The manufacturer advises that 24 additional plates can be added to the existing HX and this would reduce the approach from 15 to 9.4°C for the same heat transfer. To further reduce the approach to 5°C would require a new HX with 75 plates to replace the existing.)

b) Exhaust Gas System

Figure 26 plots stack temperature (TE 211) versus electrical load. As can be expected, the stack temperature increases with increasing electrical load. Extrapolating the curve to 100 percent electrical load indicates a maximum stack temperature of approximately 400°C. This is lower than the expected stack temperature of 527°C at 100 percent load noted by the DG unit supplier, but differences in stack diameter and resultant thermodynamic expansion has a significant cooling effect.


LAC LA MARTRE, JAN. 31, 1985

JW–HX OUTLET TEMP VS ELECT LOAD (DG 3)

FIG. No.

25

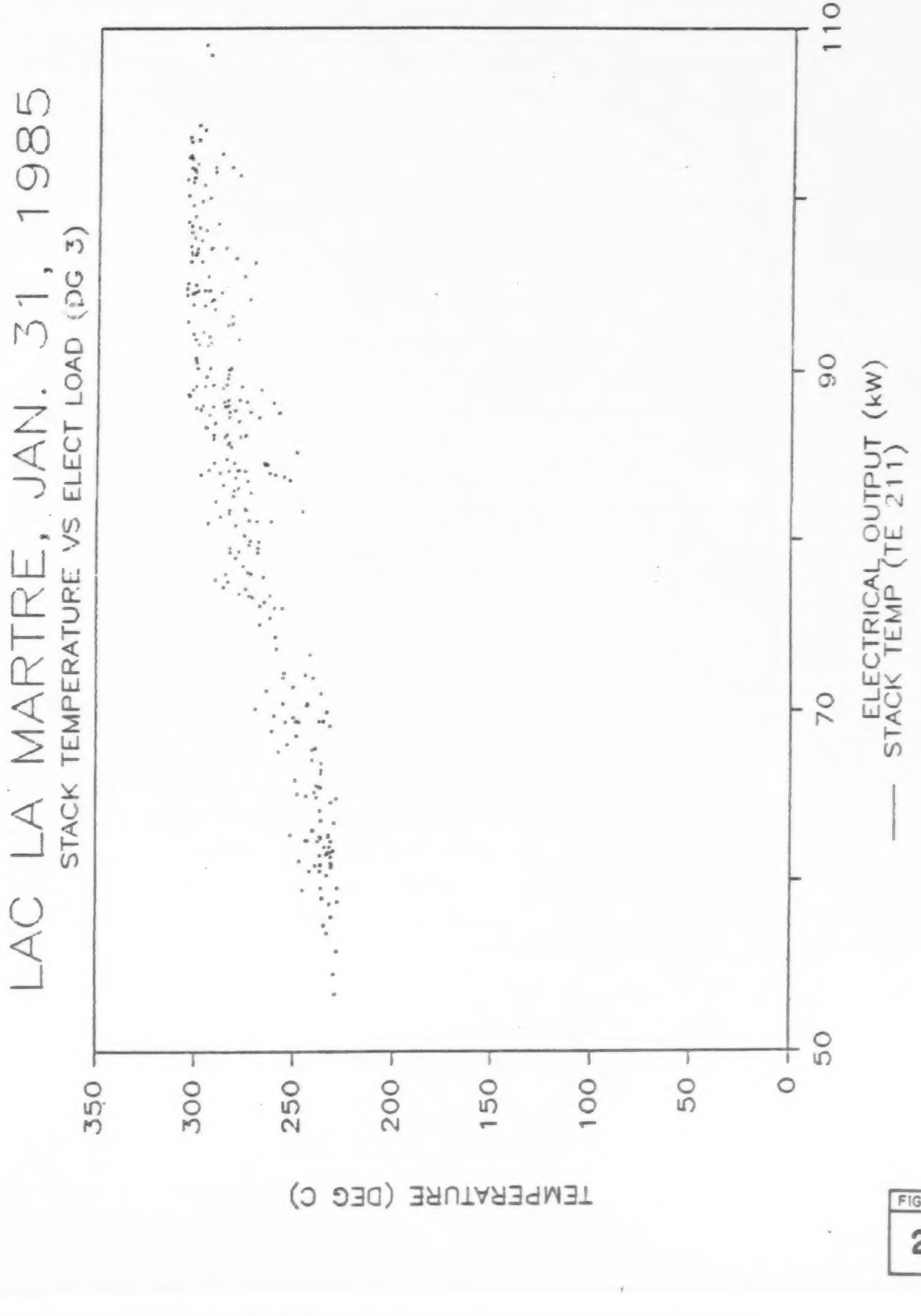

LAC LA MARTRE, JAN. 31, 1985
STACK TEMPERATURE VS ELECT LOAD (DG 3)
TEMPERATURE (DEG C)
350
300
250
200
150
100
50
0
50
70
90
110
ELECTRICAL OUTPUT (kW)
— STACK TEMP (TE 211)

FIG. No.
26

Note that the outlet temperature (TE 212), shown in Figure 27, is well below the preferred minimum temperature, and for a period of approximately 8 hours, constantly below the dew point temperature (estimated at 135°C). Although as much available heat as possible was being extracted, the temperature depression indicates an uncontrolled heat removal from the exhaust gas. (A review of the flow schematic for this site shows that neither the EXG nor the DHWS flow through the EHRS is being regulated.)

c) Domestic Hot Water System

Temperatures of DHWS to the school were generally in the 60 to 70°C range throughout the analysis period.

The existing Flow Sensor FE 408 on the DHW loop measured flow ranges from 3 to 4 L/s as compared to the recirculating pump rated flow of 2.5 L/s. Rated flow values were used to calculate the heat content of the DHWS.

d) Electrical Load Characteristics

Figure 28 plots the electrical load for a typical day. The resultant range from 60 to 110 kW compares with the average load demand of 85 kW for January 1984. A review of the average electrical demand from January 20 to February 5 as presented on Figure 29 shows a fluctuation from 60 to 85 kW with the low points occurring during the weekends. Demand from Monday to Friday is relatively stable in the 75 to 82 kW range and again compares favourably with the average demand for January 1984 noted by NCPC.

LAC LA MARTRE, JAN. 31, 1985

EXHAUST TEMPERATURE VS TIME (DG 3)

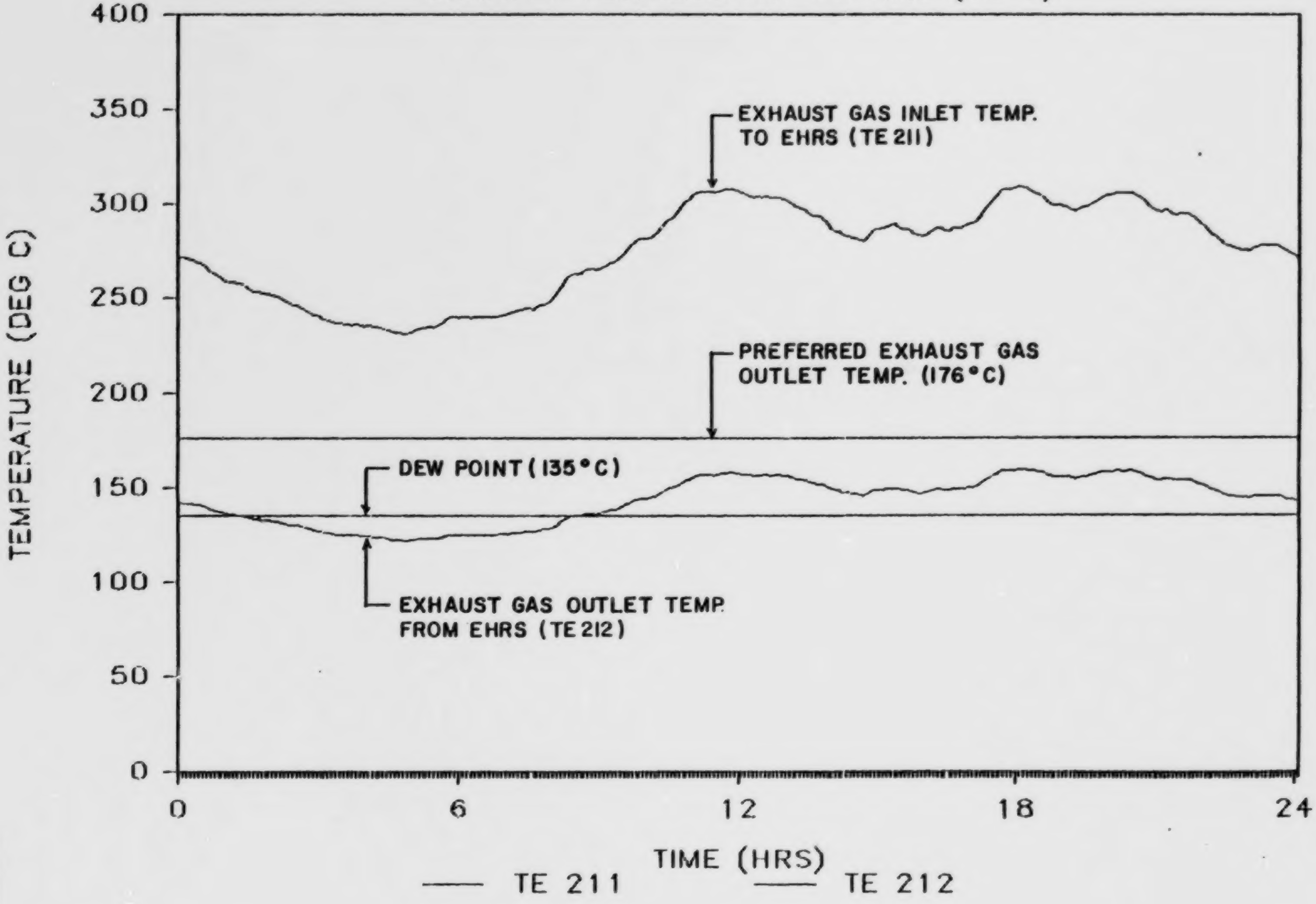


FIG. No. 27

LAC LA MARTRE, JAN. 31, 1985

ELECTRICAL LOAD VS TIME (DG 3)

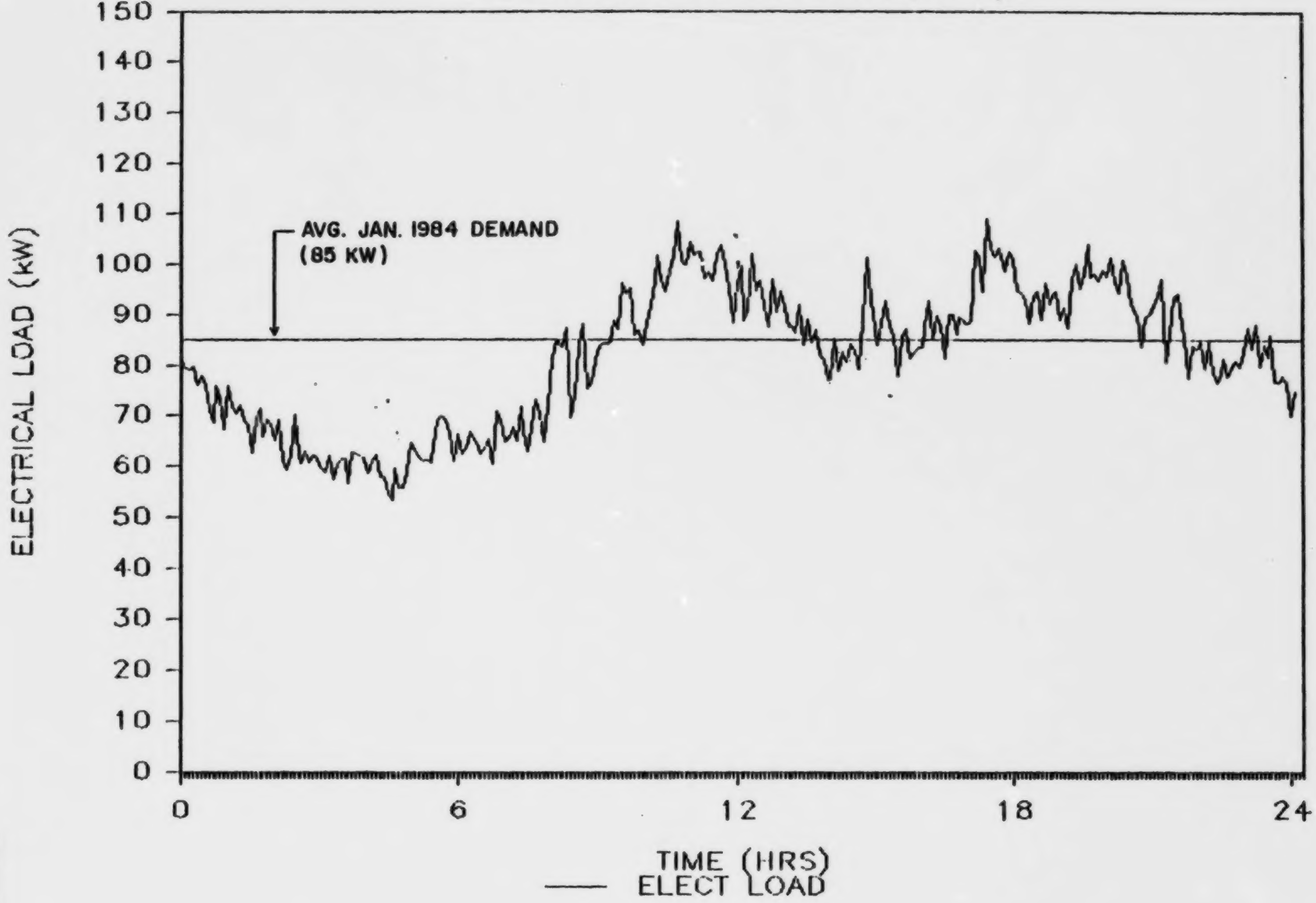


FIG. No.
28

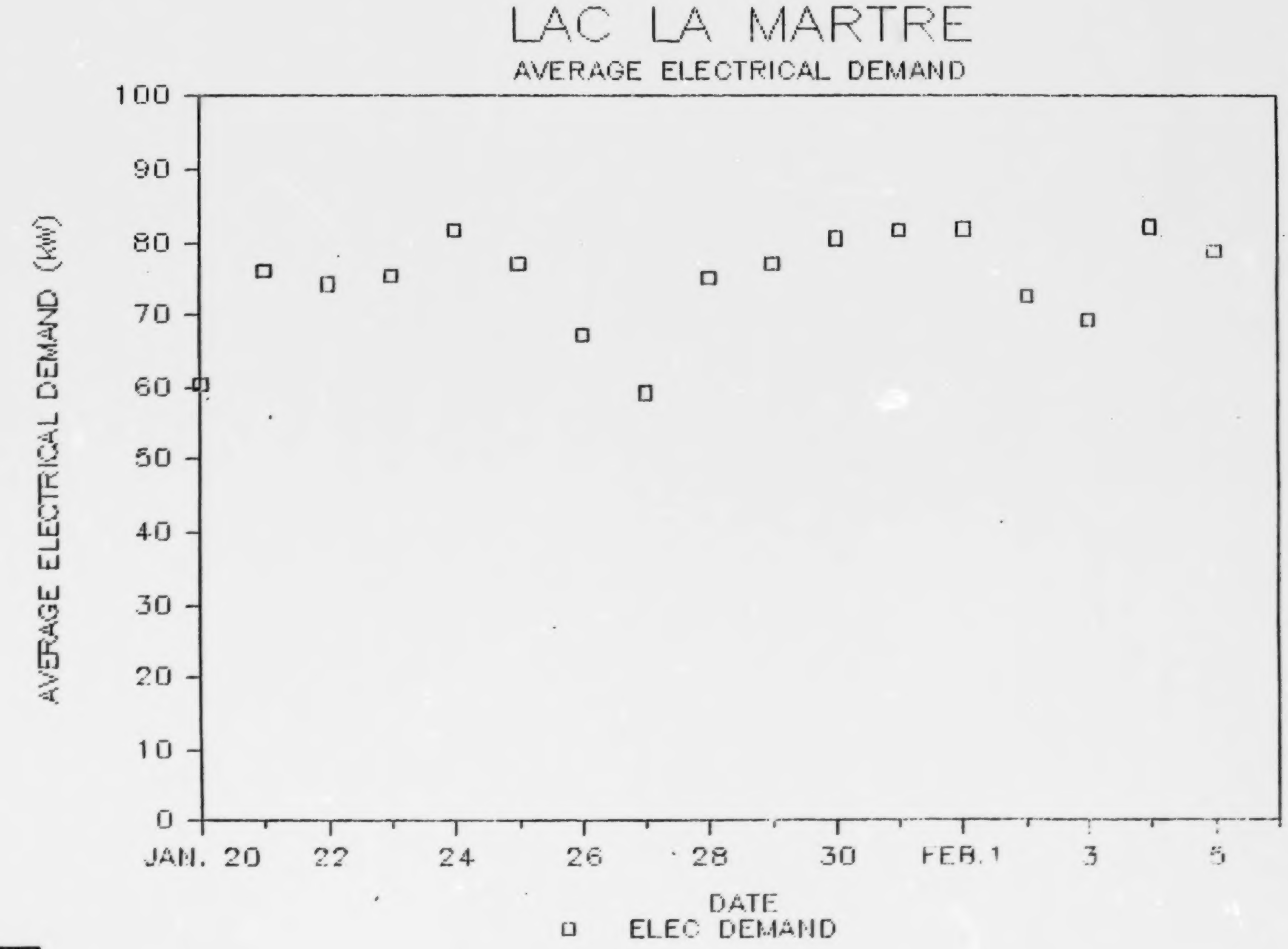

LAC LA MARTRE
AVERAGE ELECTRICAL DEMAND
AVERAGE ELECTRICAL DEMAND (kW)
100
90
80
70
60
50
40
30
20
10
0
JAN. 20
22
24
26
28
30
FEB.1
3
5
DATE
□ ELEC DEMAND

FIG. No
29

e) Jacket Water Heat Recovery Versus Electrical Load

Data on available JW heat for a typical day with DG No. 3 in operation is presented in Figure 30 and 31. These graphs show the available JW heat dropped to more realistic levels at higher electrical operating loads. At loads below 50 percent (75 kW) the available JW heat fluctuates around 2 kW/kW. As the load increases, however, the value drops to 1.4 kW/kW at 50 percent and 1.2 kW/kW at 67 percent load. This trend demonstrates the poor thermal efficiency of DG Unit No. 3 at less than 50 percent load.

From 20 to 23 January, during which period DG No. 1 was in operation, available JW heat values in the 4 to 6 kW/kW range were obtained. Since the daily electrical demand remained in the 60 to 110 kW range, this larger DG unit was operating at approximately 25 percent of design load, with consequently poor combustion and efficiency. (The data also shows that when DG 3 was restarted and DG 1 shut down, the available JW heat quickly dropped to more reasonable values.)

f) Exhaust Gas Heat Recovery Versus Electrical Load

From Figure 31 the value of 0.75 kW/kW compares with the manufacturer's projected total EXG heat value of approximately 0.9 kW/kW for this load range. Note, however, that the study results represent only about 60 percent of the total heat rejected to the exhaust.

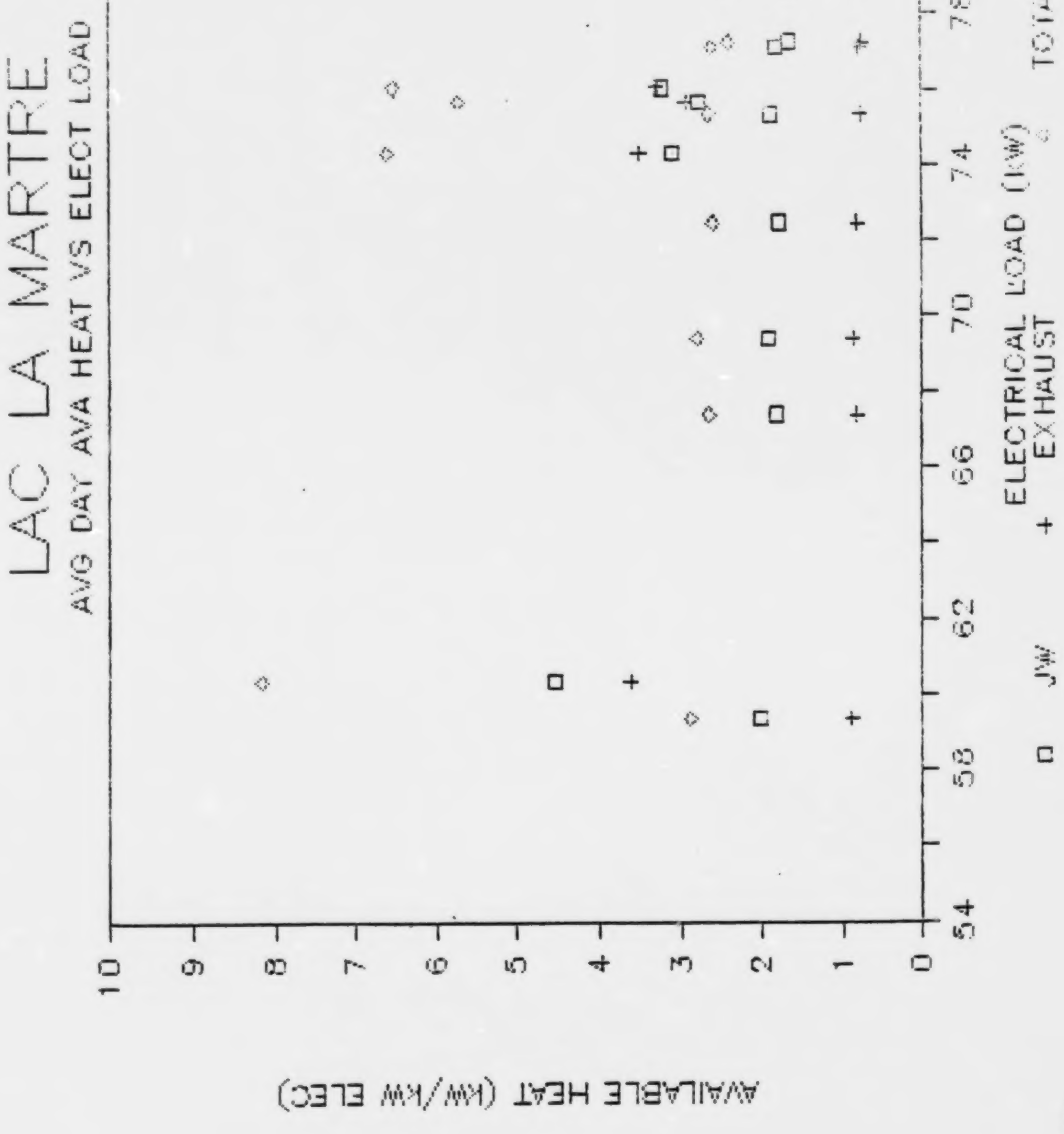

LAC LA MARTRE
AVG DAY AVA HEAT VS ELECT LOAD
AVAILABLE HEAT (KW/KW ELEC)
0
1
2
3
4
5
6
7
8
9
10
54
58
62
66
70
74
78
82
86
ELECTRICAL LOAD (KW)
□ JW
+ EXHAUST
◇ TOTAL

FIG. No. 30

LAC LA MARTRE, JAN. 31, 1985

RECOVERABLE HEAT VS ELECT LOAD (DG 3)

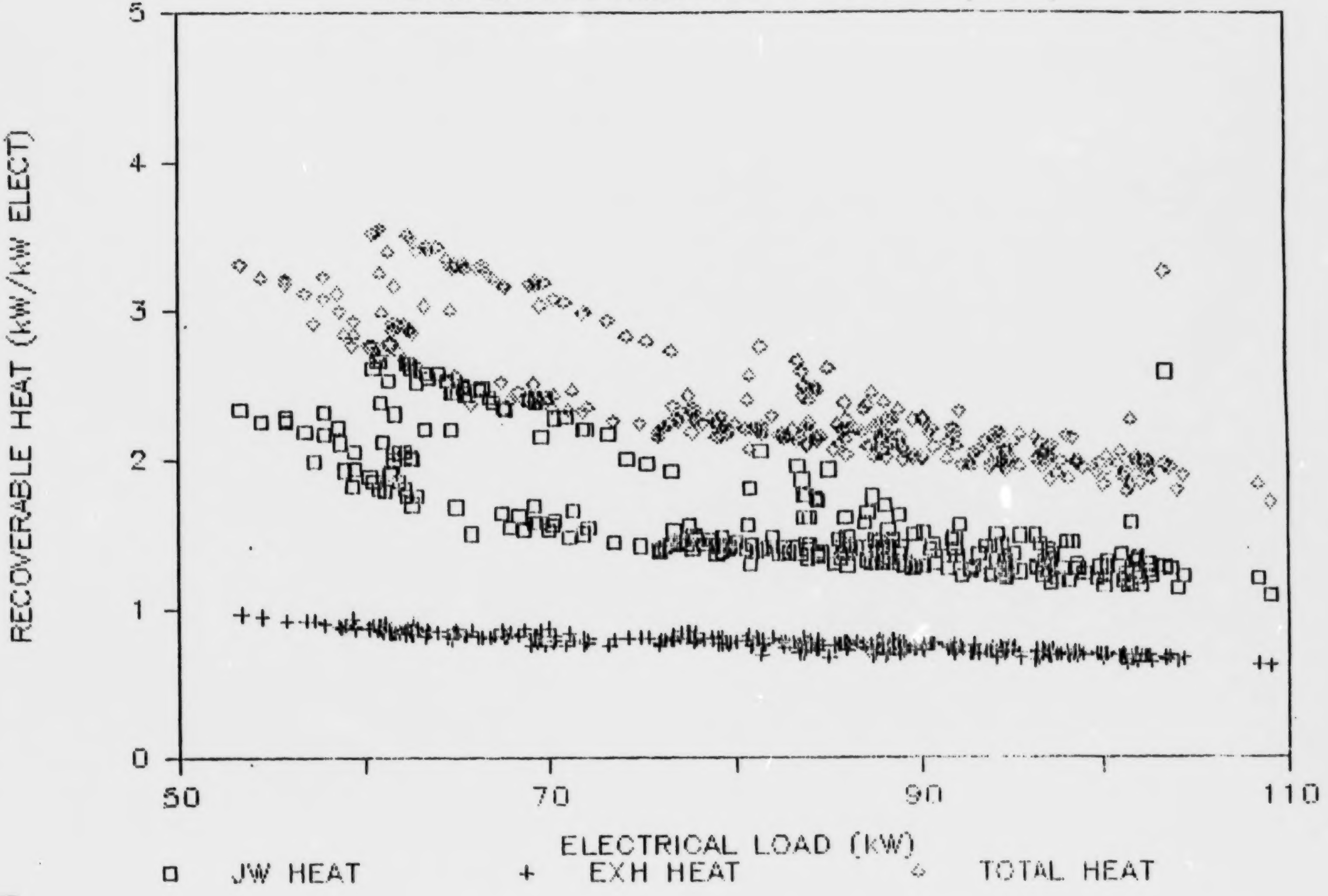


FIG. No.
31

g) Utilization of Residual Heat From Jacket Water Plus Exhaust Gas

Figure 32 plots the heat utilized by the school as a percentage of the available residual heat from JW plus EXG for a typical day. The resultant curve indicates a relatively constant utilization rate of 60 percent from about 11:00 a.m. to 2:00 a.m. Between 2:00 a.m. to 11:00 a.m., the utilization rate gradually decreases to about 4 percent by 6:00 a.m. were it holds steady until 8 a.m. and then gradually rises back to 60 percent. This fluctuation indicates that either the school controls are set back at night, or that the amount of residual heat available decreases between 2:00 a.m. to 8:00 a.m.. Reviewing Figure 28 shows that there is a similar fluctuation in the electrical load over the same time period which results in lower JW and EXG temperatures as evidenced by Figures 23 and 27.

On the longer term (disregarding January 19 to 24) the average daily percentage heat utilization is approximately 55 percent as shown in Figure 33.

Further analysis of the heat utilized by the school shows that, as presented in Figure 34, the utilization rate varies directly with the DHWS temperature. Utilization rate is defined as the amount of heat energy extracted by the school from the total heat recoverable from the JW and EXG stream. Consideration was given as to the effect of the outdoor temperature, but as can be seen from Figure 35 the rate of heat utilization remains relatively constant at approximately 60 percent in the temperature range from -23 to -33°C. Although a drop is noted at outdoor temperature below -33°C, a review of the data indicates that these lower temperatures

LAC LA MARTRE, JAN. 31, 1985

PERCENT HEAT UTILIZED VS TIME (DG 3)

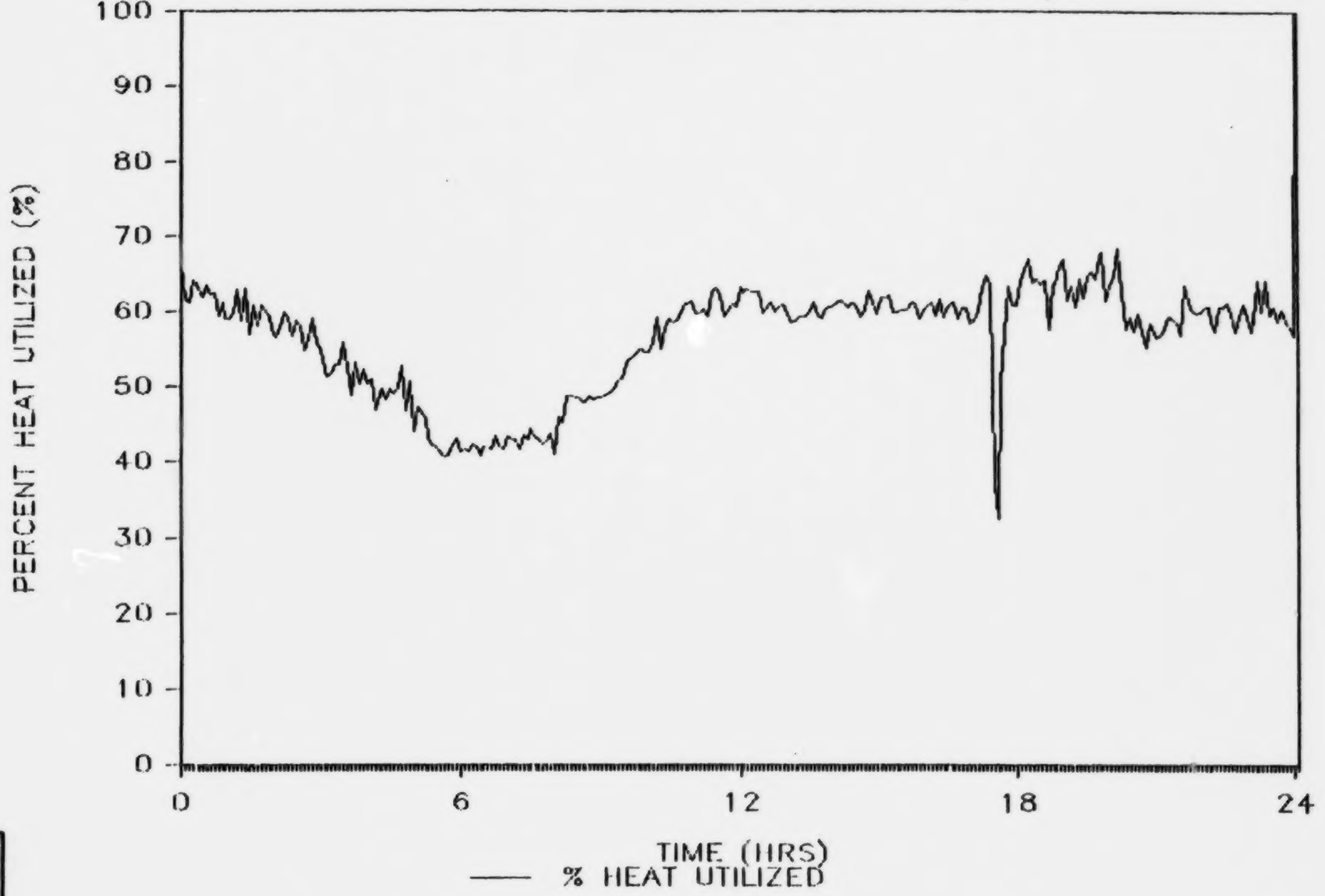
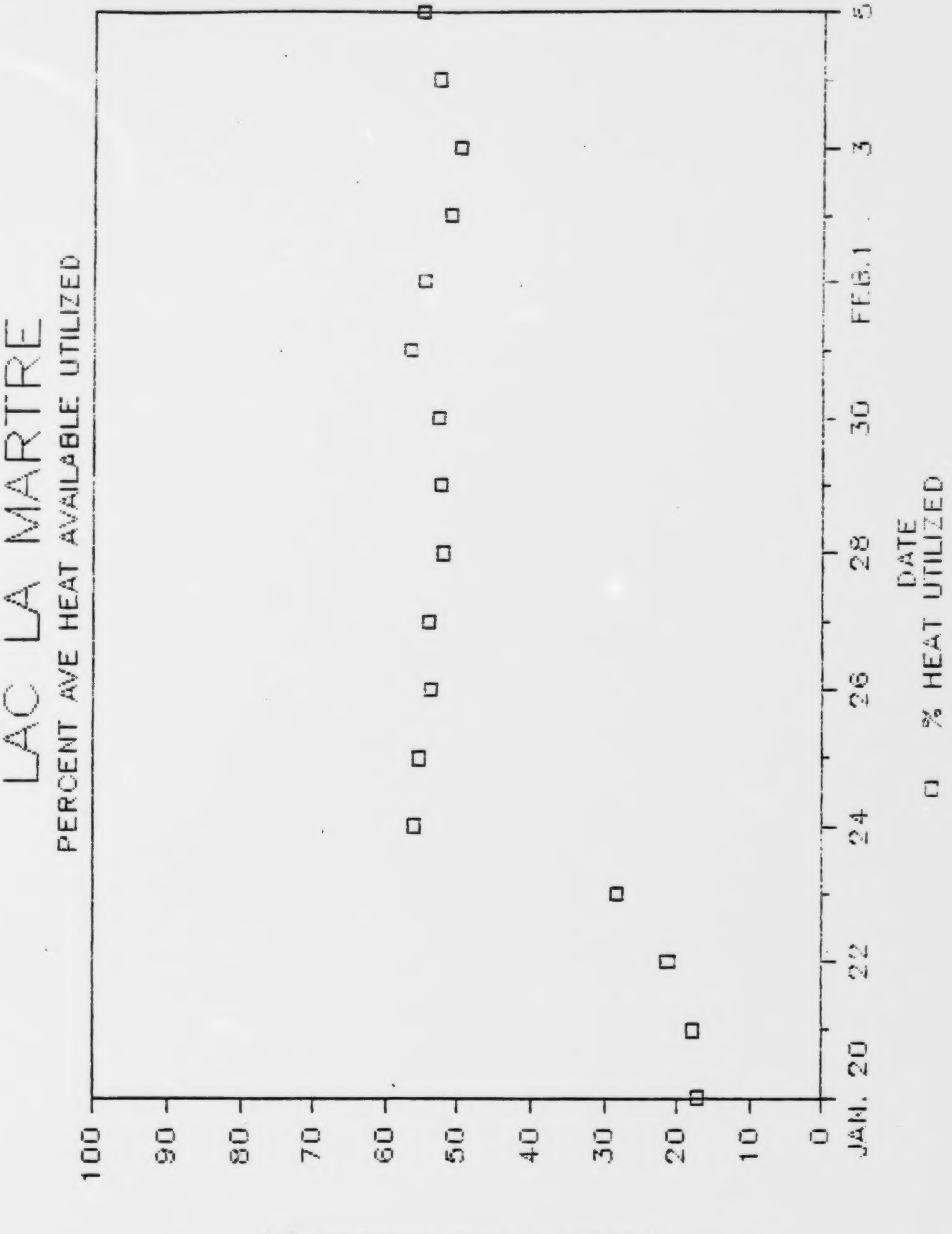


FIG. No.

32



LAC LA MARTRE

PERCENT AVE HEAT AVAILABLE UTILIZED

FIG. No.
33

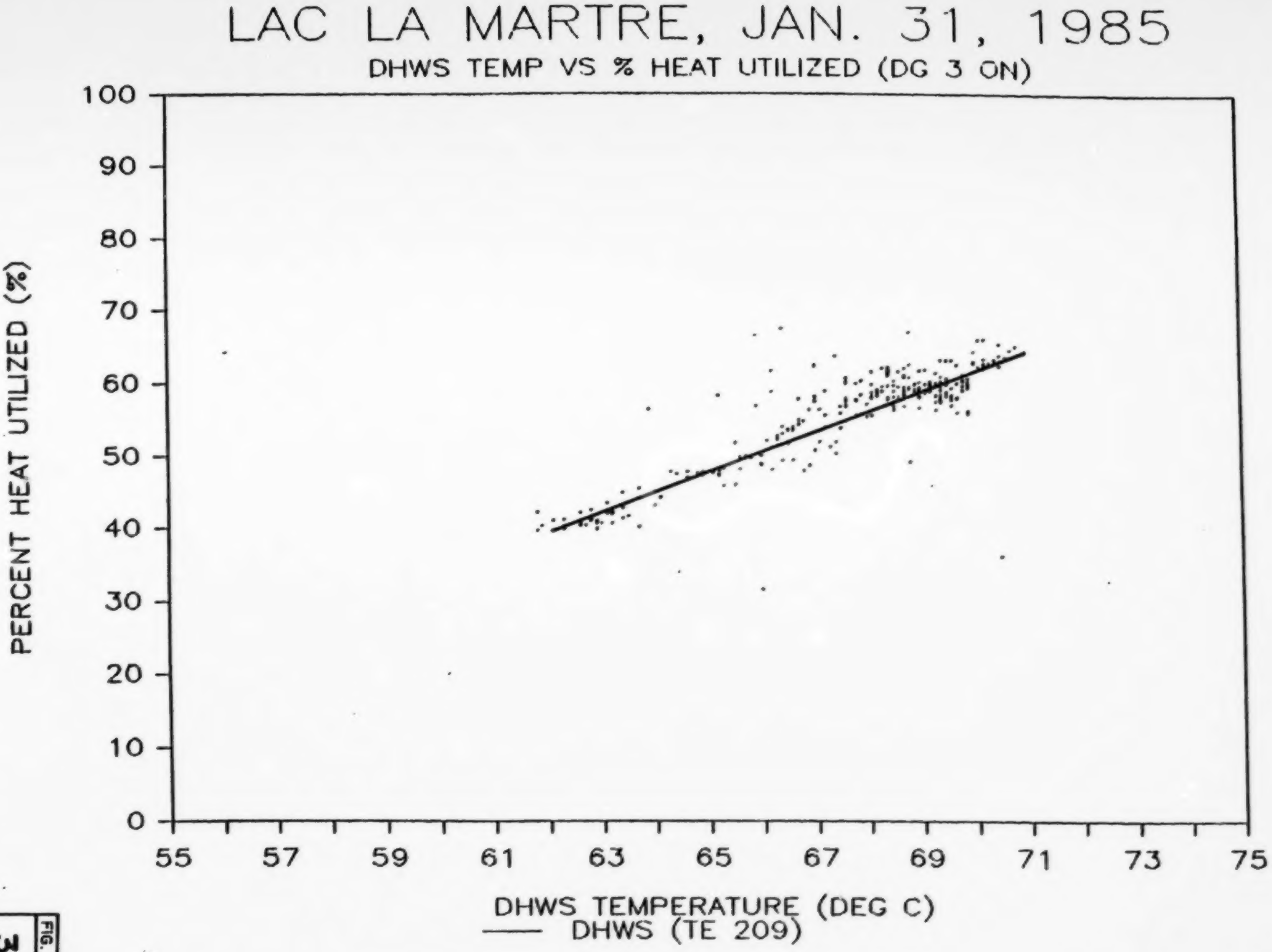
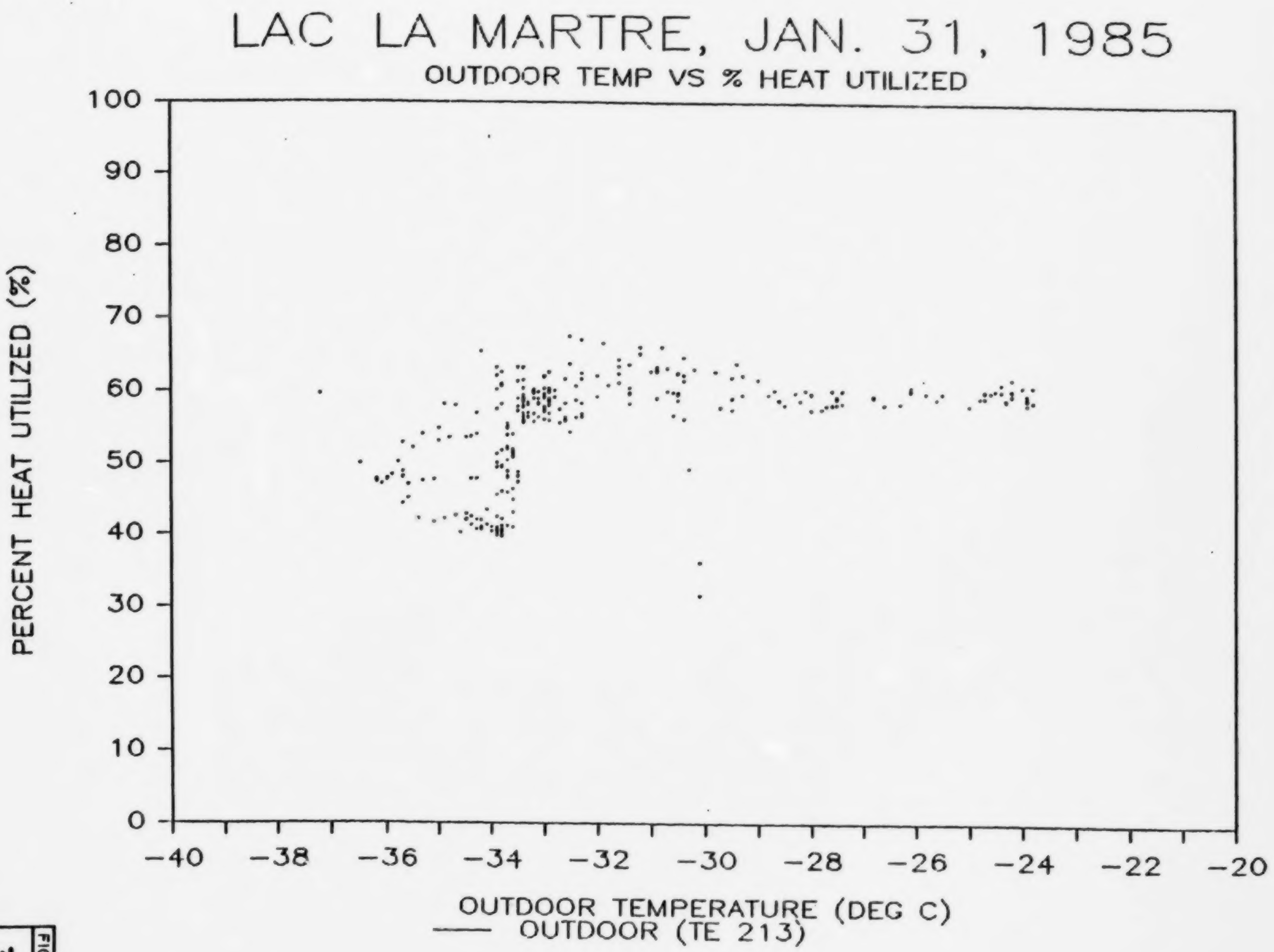

LAC LA MARTRE, JAN. 31, 1985
DHWS TEMP VS % HEAT UTILIZED (DG 3 ON)
PERCENT HEAT UTILIZED (%)
100
90
80
70
60
50
40
30
20
10
0
55
57
59
61
63
65
67
69
71
73
75
DHWS TEMPERATURE (DEG C)
DHWS (TE 209)

FIG. No.
34



LAC LA MARTRE, JAN. 31, 1985

OUTDOOR TEMP VS % HEAT UTILIZED

FIG. No.
35

occurred between 2:00 a.m. to 10:00 a.m., a period of reduced electrical load. Therefore the dip in utilization rate can be attributed to lower DHWS temperature.

h) Fuel Consumption

Similarly to Cambridge Bay, fuel usage was read off the manufacturer's characteristic fuel consumption curves. These estimated values have been compared with NCPC fuel use data as presented in Table 5. The results show that based on the reported fuel consumption, the units' thermal efficiency is approximately 27 percent. Using estimated values of fuel consumption gives an average thermal efficiency of 26 percent. Both values are in line with theoretical values for low-load conditions.

TABLE 5

LAC LA MARTRE FUEL CONSUMPTION

Date	Fuel Consumption (L)			Electrical Output kW·h
	Reported[1]	Adjusted[2]	Estimated[3]	
20 Jan		526.93	535.3	1 443.0
21 Jan		663.58	650.3	1 817.2
22 Jan		649.48	638.7	1 778.6
23 Jan		661.68	648.7	1 812.0
24 Jan		703.67	682.7	1 927.0
25 Jan		675.92	660.3	1 851.0
26 Jan		588.94	588.4	1 612.8
27 Jan		519.59	529.0	1 422.9
28 Jan		658.94	646.5	1 804.5
29 Jan		671.03	656.4	1 837.6
30 Jan		706.23	684.8	1 934.0
31 Jan		711.71	689.2	1 949.0
01 Feb		717.55	693.9	1 965.0
02 Feb		633.93	625.9	1 736.0
03 Feb		605.81	602.6	1 659.0
04 Feb		718.65	694.7	1 968.0
05 Feb		692.35	673.6	1 896.0
TOTALS	11 106	11 106.01	10 901.1	30 413.6

Note:

1. The "Reported" value is the period total provided by the NCPC Area Superintendent and records consumption of Esso Arctic #2 diesel fuel, with a heating value of 10.0 kW·h/L (155 000 Btu/Ig).

2. "Adjusted" figures are obtained by prorating "Reported" values in relation to daily electrical output.

3. "Estimated" data are from Caterpillar characteristics, which are based on diesel fuel with a heating value of 10.7 kW·h/L (166 481 Btu/Ig).

i) Theoretical Versus Actual Residual Heat Generation

As was the case in Cambridge Bay, the total energy output exceeded the fuel input energy. Adjustment of some or all of the energy inputs and outputs is necessary. Logical evaluation of the data indicates that fuel consumption and electrical output are realistic. The discrepancy must therefore be in the jacket water or exhaust gas heat data.

Compared to the expected distribution (Figure 19), the JW heat output is very high. While this is consistent with a DG operating at low load, the units poor performance makes it suspect. It is possible to check the validity of the study values by performing a heat balance across the HX. The assumed primary flow rate (FE 406) was found to be about 35 percent high, adjusted for temperature drop and compared to the secondary rate (FE 408).

The secondary flow rate was checked against the flow totalizer in the school over a three-day period of record. The latter was found to be reading about 20 percent lower than the design value of 2.5 L/s.

On this basis, it would appear that the actual jacket water heat may be in the order of 40 percent less than calculated. Adjusting the average value for a typical day (31 January 1985) provides the distribution shown in Figure 36, and tends to validate the deduced error.

LAC LA MARTRE, JAN. 31 1985

ESTIMATED ENERGY DISTRIBUTION @ 39 % LOAD

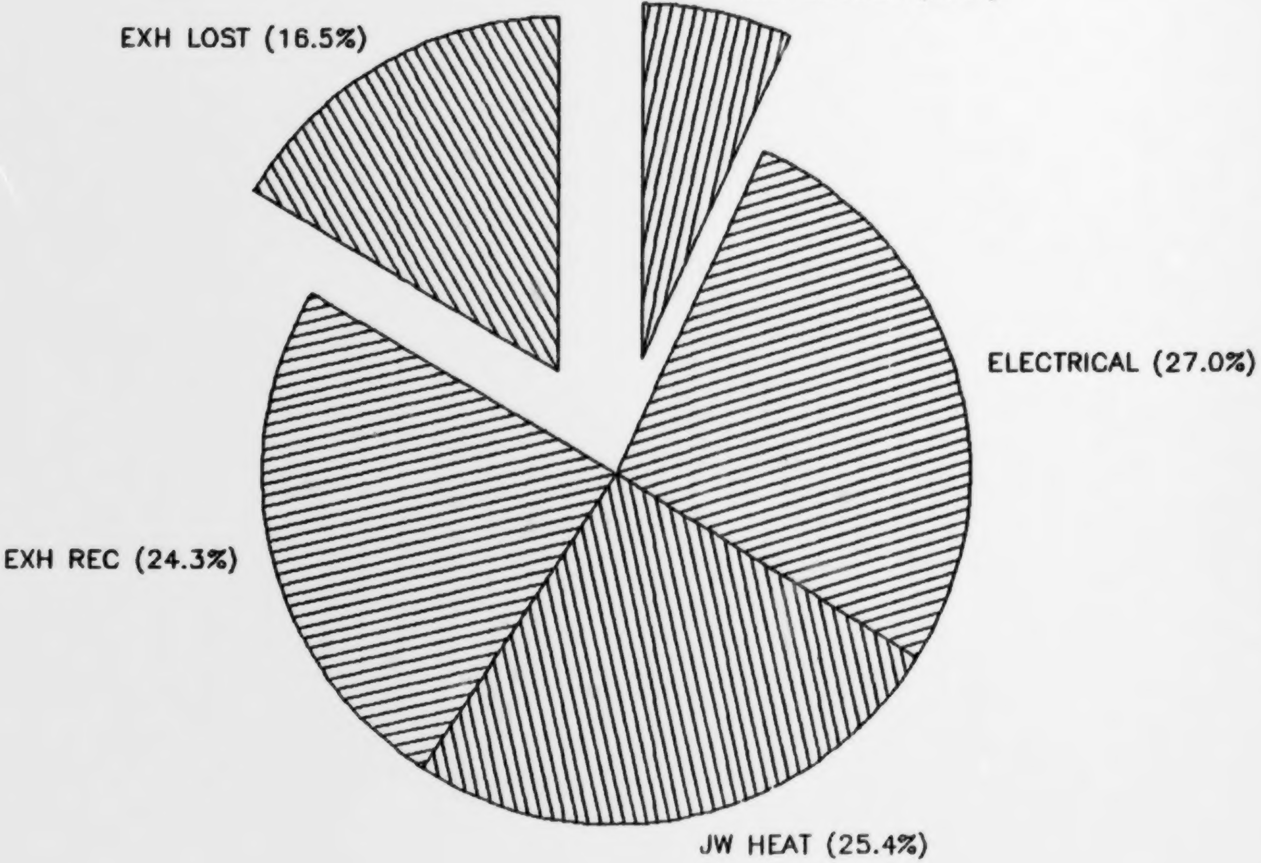


FIG. No.
36

5. EVALUATION OF EXISTING SYSTEMS AND GUIDELINES FOR NEW HEAT RECOVERY SYSTEMS

5.1 Costs Savings Evaluation of Residual Heat Utilization Systems

Substantial heating fuel oil cost savings can be realized by the utilization of residual heat from NCPC diesel generating facilities even at the low utilization efficiencies experienced during the monitoring program. The amount of fuel displaced by the recovered residual heat was calculated by dividing the total end user energy consumption by the equivalent energy value of Arctic No. 2 fuel oil (10.0 kW.h/L) assuming a boiler combustion efficiency of 80 percent. Total cost savings were based on a fuel oil price of $0.74/L for Cambridge Bay and $0.56/L for Lac La Martre.

The results of this analysis are presented in Table 6 for Cambridge Bay and Table 7 for Lac La Martre. The tables also present the anticipated fuel cost saving if close to 100 percent of the available heat was utilized. In the case of Lac La Martre, an adjustment has been made to account for the low diesel engine efficiencies experienced at reduced loads (50 percent and below) so that potential savings at 100 percent utilization are not overstated. This adjustment has been achieved by calculating a revised utilization rate for an expected available heat value of 2.0 kW/kW for a diesel generator operating at 65 percent of full load.

Allowances were also made for the transmission losses in the distribution piping system. Heat loss in the hot water distribution piping to the water treatment plant in Cambridge Bay was calculated to be 7.3 kW.h/h, or approximately 4.4 percent of the total heat energy transmitted. For evaluation purposes, it was assumed that transmission losses would be 5 percent at both sites. Consequently, the net equivalent fuel volume should be reduced by 5 percent to reflect actual fuel costs saved by the end users.

TABLE 6

FUEL COST SAVINGS FOR CAMBRIDGE BAY BASED ON ACTUAL AND 100 PERCENT UTILIZATION OF AVERAGE RESIDUAL HEAT

Date	Total Heat Available (kW/kW)	Actual Heat Utilization (%)	Calculated Fuel Cost Savings ($)	Maximum Potential Fuel Cost Savings @ 100% Utilization ($)
January 19	1.1	42.8	565.99	1 322
20	1.0	50.7	671.84	1 325
21	1.1	46.5	609.37	1 310
22	1.1	41.5	557.51	1 343
23	1.1	45.3	631.19	1 393
24	1.2	38.1	530.20	1 391
25	1.3	30.7	458.55	1 493
26	1.3	31.7	507.34	1 600
27	1.1	20.1	277.40	1 380
28	1.1	45.2	669.47	1 481
29	1.3	39.8	624.66	1 509
30	1.1	50.3	702.47	1 396
31	1.1	49.1	712.72	1 452
TOTAL			$7 518.71	$18 395
TOTAL (with 5% allowance for transmission losses)			$7 142	

TABLE 7

FUEL COST SAVINGS FOR LAC LA MARTRE BASED ON ACTUAL AND 100 PERCENT UTILIZATION OF AVERAGE RESIDUAL HEAT

Date	Total Heat Available[1] (kW/kW)	Actual Heat Utilization (%)	Revised Heat Utilization Rate[2] (%)	Calculated Fuel Cost Savings ($)	Fuel Cost Savings @ 100% Utilization ($)
January 24	2.5	56.2	69	182.37	264
25	2.4	55.7	67	166.18	248
26	2.6	53.9	71	154.19	217
27	2.9	54.5	78	153.59	197
28	2.7	52.4	70	170.76	244
29	2.6	52.7	69	173.80	252
30	2.6	53.0	68	177.62	261
31	2.4	56.7	68	182.67	268
February 1	2.4	54.9	65	176.70	272
2	2.6	51.4	67	161.92	241
3	2.8	50.0	70	156.24	223
4	2.5	53.0	65	176.39	271
5	2.5	55.3	68	178.17	262
TOTAL				$2,210.60	$3220
TOTAL (with 5% allowance for transmission losses)				$2,100	

NOTES:

1. Total heat available for diesel generator operating at approximately 50 percent load as monitored.

2. Revised heat utilization rate

$$= \left(\frac{\text{total heat available}}{\text{expected heat available}}\right) \times \text{actual heat utilization}$$

where, expected heat available = 2.0 kW/kW = 0.8 (exhaust) + 1.2 (jacket water) for diesel generator operating at approximately 60 percent load.

5.2 Assessment of System Limitations and Possible Improvements

5.2.1 Cambridge Bay

Following an evaluation of existing facilities and monitoring data for Cambridge Bay, the following system limitations were noted. Possible improvements are suggested for each limitation.

a) Jacket Water Heat Exchanger Transfer Capacity

Limitation:

- Because of the large approach temperature (difference) across the jacket water (JW) heat exchanger (HX), the district hot water supply (DHWS) temperature is frequently below the utilization temperature of 71°C as set at the water treatment plant (WTP). Therefore, heat energy extracted from the DHW loop is greatly reduced.

Improvement:

- The main shell and tube HX can be replaced with a plate-type HX designed for an approach between the hot side supply temperature and cold side discharge temperature of 5°C. This would provide a DHWS temperature in excess of 80°C, close to the required design radiation equipment supply temperature of 82°C.

b) End Users Radiation Equipment

Limitation:

- Space heating radiation equipment, having design design parameters of 82.2°C inlet and 71°C outlet temperature, cannot utilize less than 82.2°C DHWS temperature without suffering a reduction in capacity. Figure 37 shows a typical relationship of supply temperature versus radiator output.

Improvement:

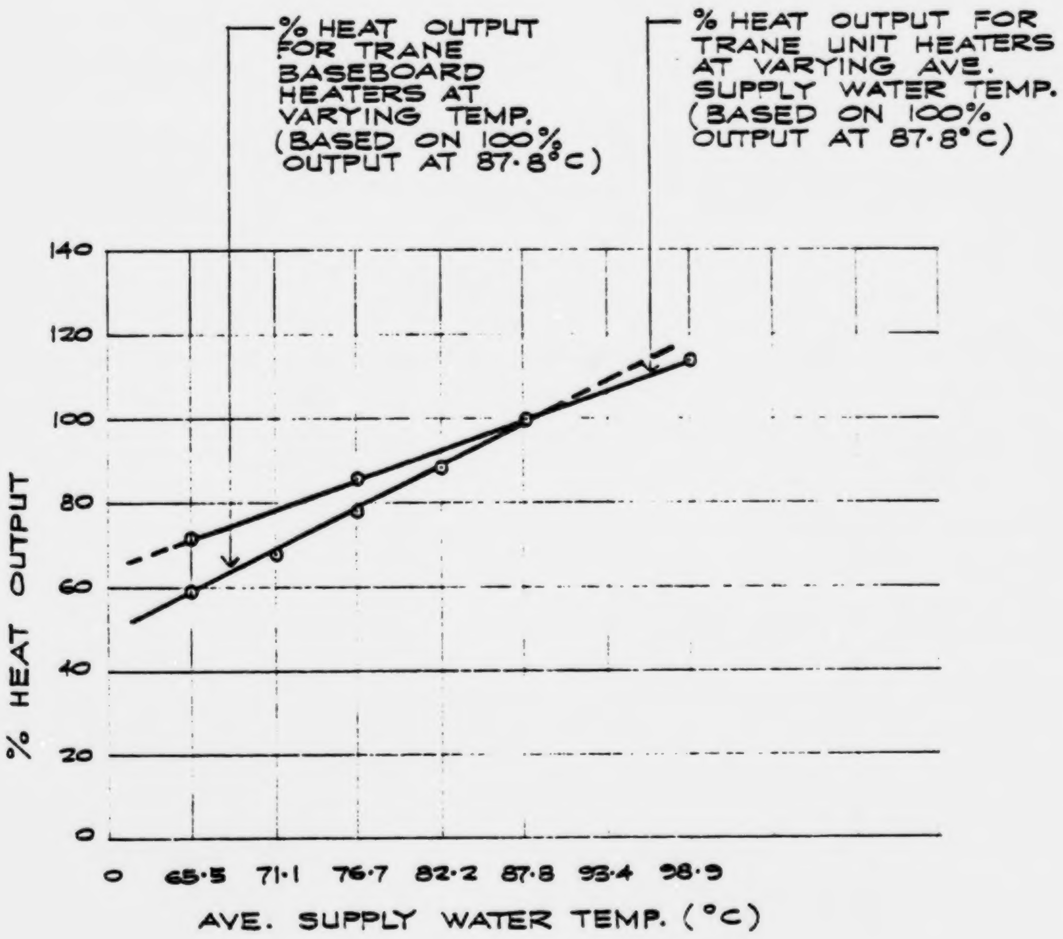
- Because of the potential for DHWS temperature below 80°C, it is suggested that the radiation units for new space heating systems, intended to utilize residual heat, be designed for DHWS temperature of 70 to 75°C and a temperature difference across the heater unit of 11.2°C. This improvement will not be necessary if the DHWS temperature is increased.

c) Three-Way Mixing Valves End Users

Limitation:

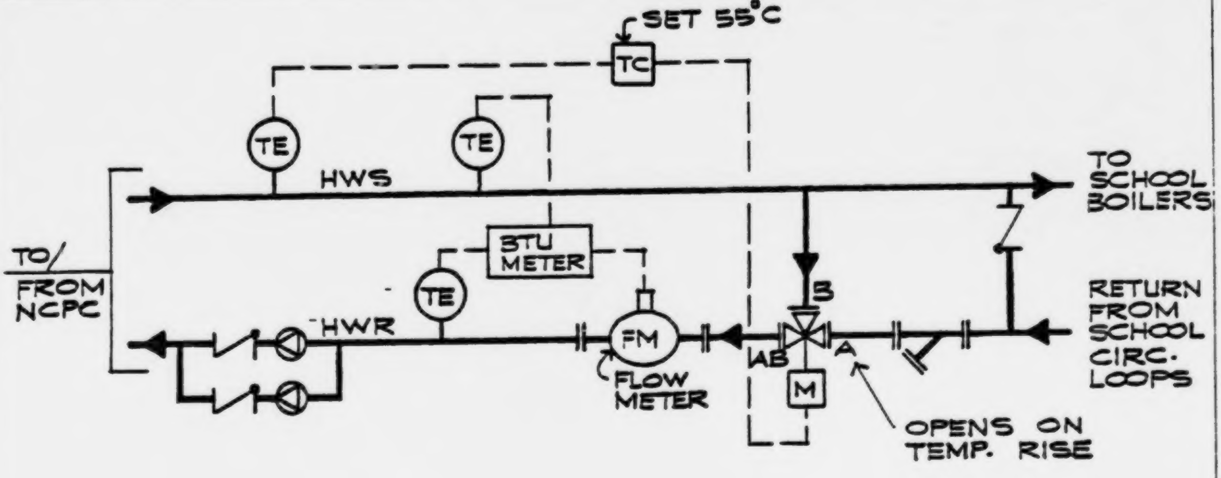
- The motorized 3-way mixing valve at the WTP as shown on Figure 38 is set to throttle the DHWS flow into the plant from full flow to zero to maintain a supply temperature to the radiators of 71°C.

  Because the DHWS temperature seldom exceeds the set temperature, the flow is less than 100 percent, thereby reducing the amount of residual heat energy which could be extracted.

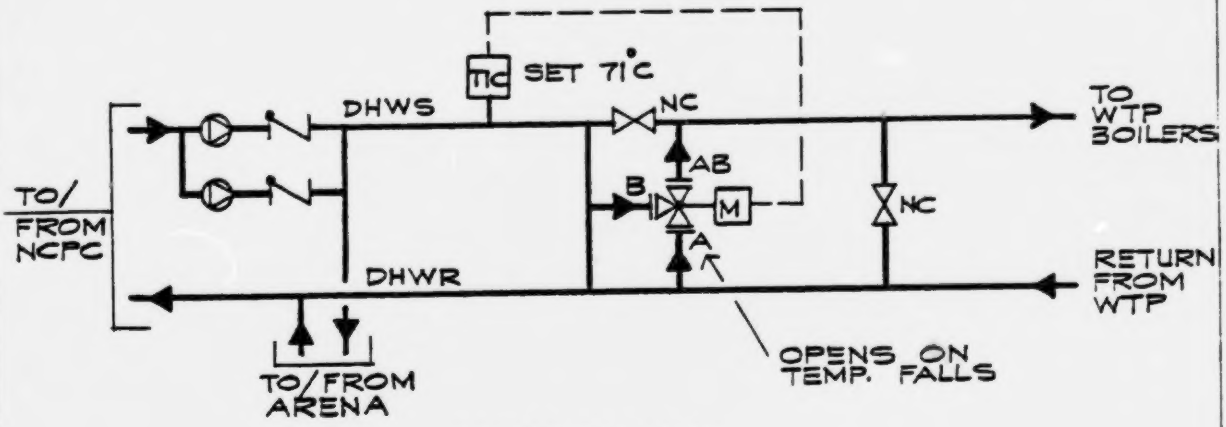


NOTE: INFORMATION FROM "THE TRANE COMPANY"

DILLON	RADIATION UNITS % HEAT OUTPUT VS. AVERAGE SUPPLY WATER TEMPERATURE	FIG. No. 37


SET 55°C
TC
TE
TE
HWS
TO SCHOOL BOILERS
TO/ FROM NCPC
BTU METER
TE
HWR
FM
FLOW METER
B
AB
A
M
RETURN FROM SCHOOL CIRC. LOOPS
OPENS ON TEMP. RISE

LAC LA MARTRE


TIC
SET 71°C
DHWS
NC
TO WTP BOILERS
AB
B
M
A
NC
TO/ FROM NCPC
DHWR
RETURN FROM WTP
OPENS ON TEMP. FALLS
TO/FROM ARENA

CAMBRIDGE BAY

LEGEND

▷	Recirculating Pump	M ⋈	Diverting Valve
TIC	Temperature Indicating Controller	⋈ NC	Shut-off Valve . Normally Closed
FM	Flow Meter	DHWS	Hot Water Supply
—N—	Check Valve	DHWR	Hot Water Return
—⋈—	Shut-off Valve	– – –	Electrical Connection to Instrumentation
TE	TEMPERATURE ELEMENT	TC	TEMPERATURE CONTROLLER

DILLON

EXISTING DISTRICT HOT
WATER SYSTEM CONNECTION

FIG. No.
38

Improvement:

- To maximize the residual heat utilization it is suggested that attempts be made to reduce the throttling range of the motorized 3-way mixing valve. Alternately, the mixing valve could be replaced with a motorized 3-way diverting valve and snap action controller set to utilize full flow at any temperature above the preset lower limit, as shown in Figure 39, Alternative 1. In either case, outdoor reset mode could be added to the controller, to obtain utilization of low temperature residual heat when ambient conditions allow.

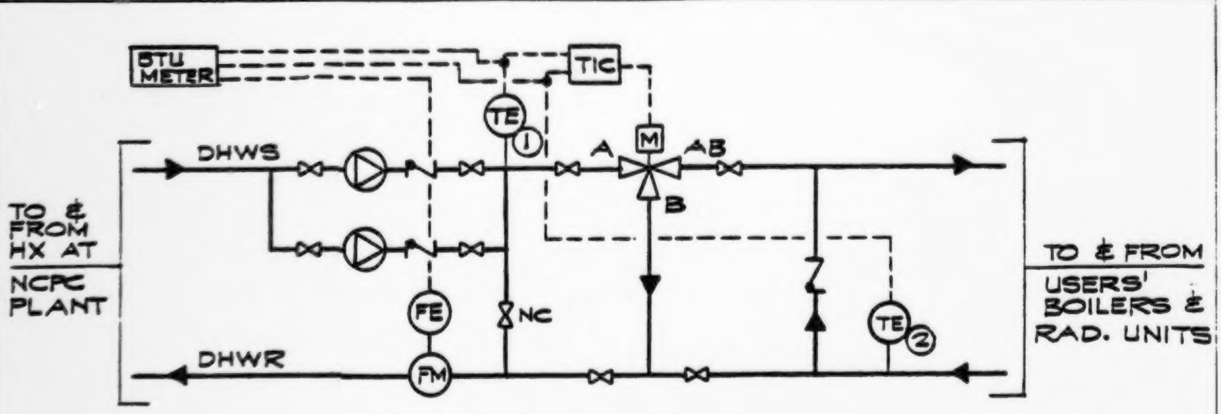
d) End User Manual Control Valves

Limitation:

- Manual switchover is required to utilize DHWS for heating. Switchover becomes solely the boiler operator's responsibility and the utilization of the DHWS rests entirely in his judgment. Furthermore, once switched over to the DHWS system, at low DHWS temperature (below the normal boiler set point of 71°C), heat can flow from the carpentry shop boiler back to the NCPC station as the DHWR temperature will exceed the DHWS temperature.

Improvement:

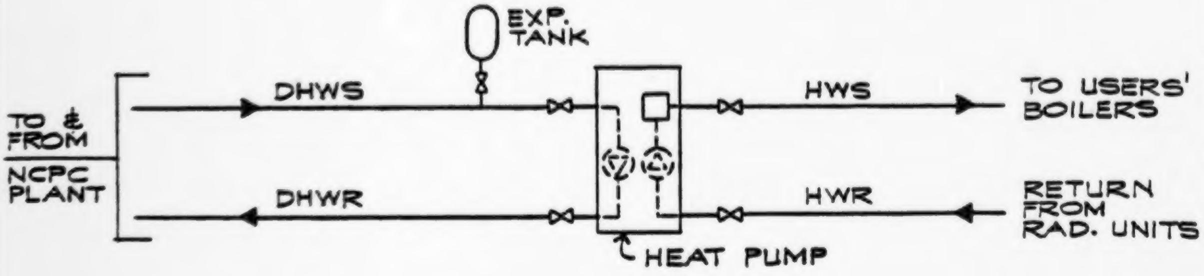
- Replace the manual switchover valve in the carpentry shop with a motorized three-way diverting valve. See Figure 39, Alternative 1.


BTU METER
TIC
TE ①
M
A
AB
B
DHWS
DHWR
TO & FROM HX AT NCPC PLANT
FE
FM
NC
TE ②
TO & FROM USERS' BOILERS & RAD. UNITS

ALTERNATIVE I - DIRECT UTILIZATION OF DHWS

TIC COMPARES SUPPLY WATER TEMP. AT ① TO RETURN WATER TEMP. AT ②

- IF ① > ②, FLOW IS DIRECTED FROM A TO AB
- IF ① < ②, FLOW IS DIRECTED FROM A TO B


EXP. TANK
DHWS
DHWR
HWS
HWR
TO & FROM NCPC PLANT
TO USERS' BOILERS
RETURN FROM RAD. UNITS
HEAT PUMP

ALTERNATIVE 2 - UPGRADE DHWS TO HIGH TEMPERATURE

LEGEND

▷	Recirculating Pump	M ⋈	Diverting Valve
TIC	Temperature Indicating Controller	⋈ NC	Shut-off Valve . Normally Closed
FM	Flow Meter	DHWS	Hot Water Supply
⊣	Check Valve	DHWR	Hot Water Return
⋈	Shut-off Valve	----	Electrical Connection to Instrumentation

DILLON	DISTRICT HOT WATER SYSTEM CONNECTION AT END USER	FIG. No. 39

e) Heat Recovery Piping in NCPC Plant

Limitation:

- Overly complex piping system complicates operation and unduly increases friction losses in the system.

Improvement:

- Stream line heat recovery plant system.

5.2.2 Lac La Martre

A review of the Lac La Martre Heat Recovery System and the monitoring data revealed the following system limitations. Possible improvements are suggested for each limitation.

a) JW Heat Exchanger Transfer Capacity

Limitation:

- Approach temperature on the JW heat exchanger (HX) ranges from 14 to 16°C and is too high. HX has insufficient heat transfer area and thereby limits the amount of heat available from this source.

Improvement:

- Add plates to the existing HX, or for ultimate performance replace with a plate-type unit designed for an approach temperature of 5°C.

b) Diesel Generator Cooling System

Limitation:

- Temperature rise across the diesel engine jacket cooling water system is too high for DG No. 1 (11-15°C).

- JW inlet temperature averaging 60°C (see Figure 22) is lower than the recommended minimum of 74°C and may induce thermal stresses on the DG unit.

Improvement:

- Eliminate short circuiting potential in JW system by installation of control valves or check valves on each engine.

- Do not use DG No. 1 at low loads or increase JW flow rate.

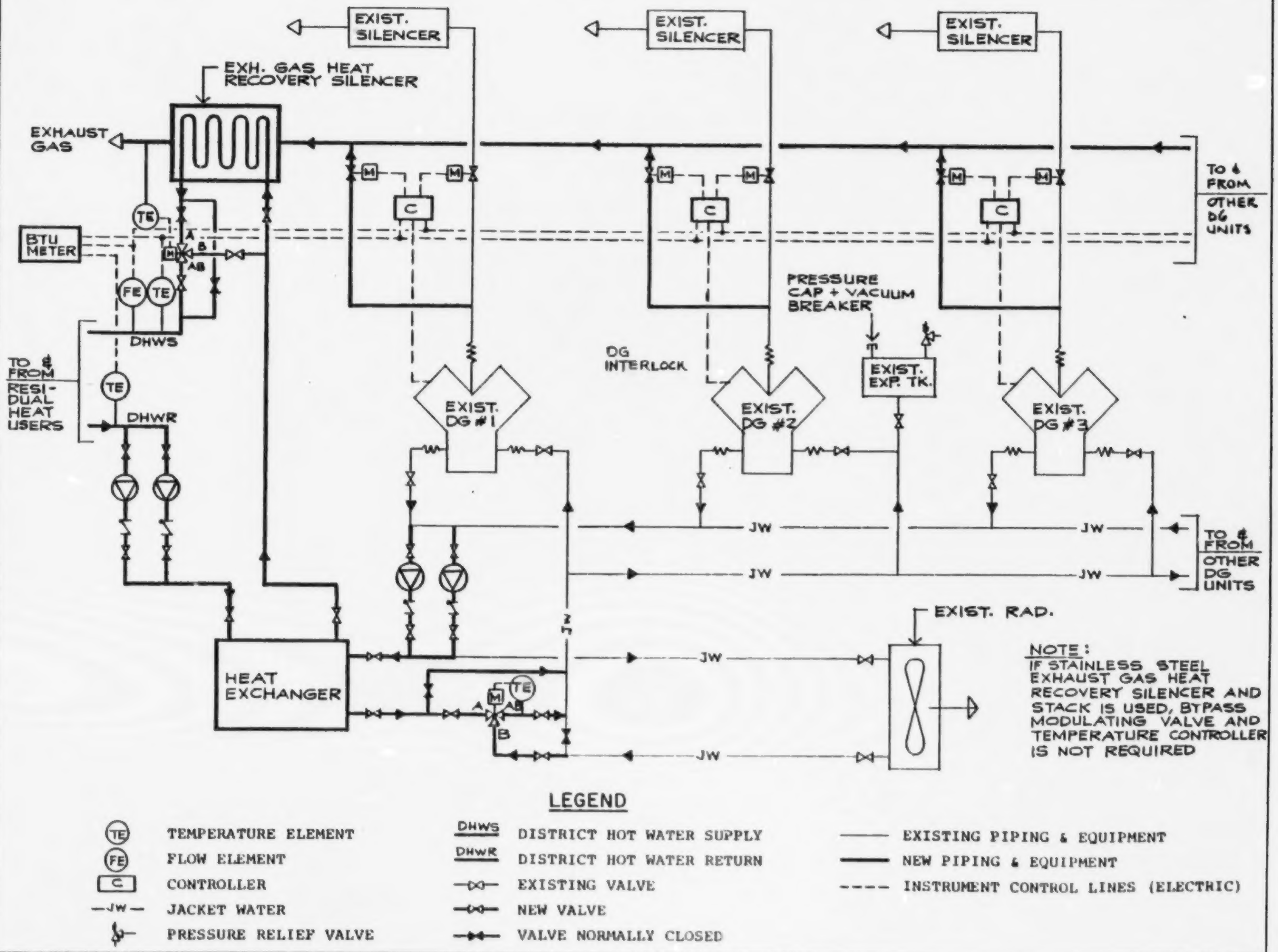
c) Exhaust Gas Heat Recovery System

Limitation:

- The exhaust gas (EXG) discharge temperature drops below the dew point (135°C), condensation occurs and the resulting acidic condensate can corrode the pipe as well as the exhaust gas heat recovery silencer (EHRS).

Improvement:

- Install a three-way motorized mixing valve on the DHWS system downstream of the EHRS as shown on Figure 40.


EXIST. SILENCER
EXIST. SILENCER
EXIST. SILENCER
EXH. GAS HEAT RECOVERY SILENCER
EXHAUST GAS
TE
BTU METER
A
B
AB
M
FE
TE
DHWS
TO & FROM RESI-DUAL HEAT USERS
TE
DHWR
M
C
M
TO & FROM OTHER DG UNITS
PRESSURE CAP + VACUUM BREAKER
DG INTERLOCK
EXIST. EXP. TK.
EXIST. DG #1
EXIST. DG #2
EXIST. DG #3
JW
TO & FROM OTHER DG UNITS
EXIST. RAD.
HEAT EXCHANGER
TE
M
A
AB
B
LEGEND
TE TEMPERATURE ELEMENT
FE FLOW ELEMENT
C CONTROLLER
—JW— JACKET WATER
PRESSURE RELIEF VALVE
DHWS DISTRICT HOT WATER SUPPLY
DHWR DISTRICT HOT WATER RETURN
EXISTING VALVE
NEW VALVE
VALVE NORMALLY CLOSED
EXISTING PIPING & EQUIPMENT
NEW PIPING & EQUIPMENT
INSTRUMENT CONTROL LINES (ELECTRIC)

NOTE: IF STAINLESS STEEL EXHAUST GAS HEAT RECOVERY SILENCER AND STACK IS USED, BYPASS MODULATING VALVE AND TEMPERATURE CONTROLLER IS NOT REQUIRED

DILLON

PROPOSED RESIDUAL HEAT RECOVERY SYSTEM
FOR NCPC PLANTS - ALTERNATIVE I

FIG. No
40

- Alternately, the existing EHRS can be replaced with a stainless steel unit to allow for maximum heat extraction without corrosion.

5.2.3 General

a) DHW Loop Flow Control and Monitoring

Limitation:

- Lack of information on system performance as well as specific items pertaining to Cambridge Bay and Lac La Martre (i.e. less than optimum heat utilization, heat flow reversal, low exhaust gas temperature).

Improvement:

- Three-way diverting valve would be installed complete with temperature sensors on both the DHWS and DHWR pipe connections, along with a BTU meter, to record total heat energy transferred to user and to alarm in case of a potential heat energy flow reversal. (Figure 39, Alternative 1). (Before doing this, attempts should be made to modify existing valve and controller to give similar action of a diverting valve.)

5.3 Summary of Design Guidelines for New Heat Recovery/Distribution Installations

As a result of this study, the following design guidelines are suggested for new heat recovery/distribution installations. These guidelines are not all inclusive and arise only from the limited scope of work under this study. They should not therefore be solely used to the exclusion of other guidelines which may relate to other aspects of the heat recovery/distribution system.

- Install controls on the water loop to maintain the EXG temperature above 134°C and preferably between 150 to 175°C immediately downstream of EHRS. If a higher level of heat extraction from the EXG stream is desirable, EHRS and stack downstream of EHRS should be of stainless steel.

- EHRS must be selected and installed such that the total back pressure on the DG unit does not exceed the engine rating (which ranges from 5 to 7.5 kPa).

- The flow rate in the JW loop is normally selected by the equipment manufacturer for an 8.3°C temperature rise across the DG unit. In extending the JW loop and going through a HX, additional pressure drop will be incurred. A detailed analysis must be undertaken to ensure that the JW flow rate is maintained within the design range by the existing or new circulation pumps.

- Install 3-way diverting valve complete with outdoor reset control and energy monitoring meter at each end user connection.

- Design JW/DHW HX for an approach temperature not to exceed 5°C.

- Maintain DHWS temperature in the 80 to 85°C range.

6. RESIDUAL HEAT RECOVERY FROM OTHER NCPC PLANT SITES

6.1 General

Based on the findings from the monitoring of the Cambridge Bay and Lac La Martre sites (as discussed under sections 4 and 5), this section identifies the heat recovery and utilization potential of the other 37 candidate sites. Initially, the findings are applied to calculate the quantity of heat energy which could be available at each site. Next, alternative methods of recovering the available heat energy are discussed. An investigation of potential users and their respective net energy requirements follows. This section concludes with a discussion on alternative methods which could be used to distribute the recoverable residual heat energy.

6.2 Potential Heat Recovery Available for Each Site

The amount of residual heat available from each site has been calculated on the basis of the following criteria and is presented in Tables 8 and 9.

- Ratio of heat recovered from the jacket cooling water loop per kW of electrical output as calculated from monitoring data of Cambridge Bay and Lac La Martre - 1.1 kW heat output per 1 kW of electrical load.

- Ratio of heat recovered from the exhaust gas per kW of electrical output - calculated as 0.7 kW per kW of electrical load based on the results from Cambridge Bay and Lac La Martre which show 0.65 and 0.75 kW/kW respectively.

- NCPC 1985-86 forecast of peak electrical load and annual load factor as provided by NCPC (Table 8).

TABLE 8

TOTAL CALCULATED RESIDUAL HEAT AVAILABLE

(based on the forecast electrical generation peak multiplied by the projected load factor for 1985-86)

Site	Total Installed Diesel Generator Capacity kW	Forecast Peak Electrical Load kW 85-86	NCPC Load Factor %	Heat Available From Jacket Water (1.1 kW/kW) kW 85-85	Heat Available From Ex Gas (0.7 kW/kW) kW 85-86	Total Heat Available (1.8 kW/kW) kW 85-86
Aklavik	1500	577	48	305	194	499
Arctic Bay	1050	353	44	171	109	280
Arctic Red River	280	69	67	51	32	83
Baker Lake	2174	839	57	526	335	861
Broughton Island	630	231	58	147	94	241
Cambridge Bay	2375	1044	54	620	395	1015
Cape Dorset	1500	611	50	336	214	550
Chesterfield Inlet	650	199	47	103	65	168
Clyde River	1100	322	58	205	131	336
Coppermine	1575	676	49	364	232	596
Coral Harbour[1]	1350	655	48	346	220	566
Eskimo Point	1800	743	52	425	270	695
Fort Franklin	800	401	41	181	115	296
Fort Good Hope	900	349	41	157	100	258
Fort Liard	735	138	56	85	54	139
Fort McPherson	1280	634	44	307	195	502
Fort Norman	950	320	43	151	96	248
Fort Simpson	5485	834	78	716	455	1171
Gjoa Haven	1160	449	46	227	145	372
Grise Fiord	415	128	50	70	45	115
Hall Beach	785	230	60	152	97	248
Holman Island	850	263	47	136	87	222
Igloolik	1200	543	54	323	205	528
Jean Marie River	61	19	34	7	5	12
Lac La Martre	375	171	42	79	50	129
Lake Harbour	750	214	57	134	85	220
Nahanni Butte	151	21	53	12	8	20
Pangnirtung	1800	671	47	347	221	568
Paulatuk	575	207	37	84	54	138
Pelly Bay	800	228	48	120	77	197
Pond Inlet	1620	696	49	375	239	614
Rae Lakes	260	86	37	35	22	57
Rankin Inlet	2720	1572	55	951	605	1556
Repulse Bay	750	218	61	146	93	239
Sachs Harbour	800	255	56	157	100	257
Snowdrift	430	140	45	69	44	113
Spence Bay	900	512	46	259	165	424
Whale Cove	650	166	52	95	60	155
Wrigley	480	52	89	51	32	83

Notes: 1. 600 kW downtown, 750 kW by MOT.

TABLE 9

TOTAL CALCULATED RESIDUAL HEAT AVAILABLE (based on average monthly electrical demand for January 1984)

Site	Total Installed Diesel Generator Capacity kW	January 1984 Average Monthly Demand kW	Heat Available From Jacket Water (1.1 kW/kW) kW	Heat Available From Ex Gas (0.7 kW/kW) kW	Total Heat Available (1.8 kW/kW) kW
Aklavik	1500	340	374	238	612
Arctic Bay	1050	178	196	125	320
Arctic Red River	280	47	57	33	85
Baker Lake	2174	547	602	383	985
Broughton Island	630	210	231	147	378
Cambridge Bay	2375	578	636	405	1040
Cape Dorset	1500	362	398	253	652
Chesterfield Inlet	650	133	146	93	239
Clyde River	1100	211	232	148	380
Coppermine	1575	393	432	275	707
Coral Harbour[1]	1350	370	407	259	666
Eskimo Point	1800	476	524	333	857
Fort Franklin	800	136	150	95	245
Fort Good Hope	900	196	216	137	353
Fort Liard	735	104	114	73	187
Fort McPherson	1280	344	378	241	619
Fort Norman	950	181	199	127	326
Fort Simpson	5485	857	943	600	1543
Gjoa Haven	1160	214	235	150	385
Grise Fiord	415	78	86	55	140
Hall Beach	785	166	183	116	299
Holman Island	850	160	176	112	288
Igloolik	1200	323	355	226	581
Jean Marie River	61	4	4	3	7
Lac La Martre	375	85	94	60	153
Lake Harbour	750	158	174	111	284
Nahanni Butte	151	16	18	11	29
Pangnirtung	1800	385	424	270	693
Paulatuk	575	83	91	58	149
Pelly Bay	800	142	156	99	256
Pond Inlet	1620	414	455	290	745
Rae Lakes	260	37	41	26	67
Rankin Inlet	2720	873	960	611	1571
Repulse Bay	750	178	196	125	320
Sachs Harbour	800	158	174	111	284
Snowdrift	430	72	79	50	130
Spence Bay	900	260	286	182	468
Whale Cove	650	133	146	93	239
Wrigley	480	28	31	20	50

Notes: 1. 600 kW downtown, 750 kW by MOT.

- NCPC average monthly demand for January 1984 (Table 9).

Because the average electrical demand for January 1984 is higher than the forecast average annual load (based on forecast electrical load x forecast NCPC load factor), the available heat for each site is greater when the average monthly load factor for January 1984 is applied. However, to determine the fuel cost savings resulting from utilization of the available heat, it is suggested that the lower more conservative values as presented in Table 8 be used. Likewise, these values should be used to design the heat recovery/distribution system.

The use of conservative available heat values is supported by the realization that the heat required by the end users may not always coincide with the variation in the average monthly electrical load demand. Therefore, the heat available, may not be fully required by the end users.

An attempt was made to relate average monthly load variation to total month sunshine hours which were in turn related to heat demand by the end user. These results are included in Appendix "D". In general, however, although a relationship does exist, it could not be used to accurately assess the available heat from the NCPC plant.

6.3 Alternative Methods for Recovering Residual Heat

Several alternative methods for recovering residual heat were considered. The heat recovery system should be designed as not to interfere or otherwise restrict the normal operation of the generating plant. Each alternative requires several components, such as exhaust gas heat recovery silencer (EHRS), a jacket water (JW) heat exchanger (HX), a 3-way motorized diverter valve and associated piping and valves. For purposes of this study, JW recirculating booster pumps are included with each alternative; but final design analysis may reveal that they are not required.

Because of the excess generating capacity at each NCPC station, which ranges from 2 to 9 times the forecast peak electrical load (Table 8), it would be wasteful to install heat recovery equipment on all diesel generator (DG) units. Heat recovery equipment should only be installed on most frequently used DG units and should not be installed on standby DG units. However, it may be possible to combine the exhaust gas streams through one stack on which the EHRS could be installed.

a) Alternative 1

As shown on Figure 40, JW is pumped, in a closed loop, from the DG units, through a plate heat exchanger (HX) and returned to the DG units maintaining a temperature range of 74°C to 90°C. If the JW exceeds this temperature range it is diverted through the existing radiators for additional cooling. The exhaust gas (EXG) is diverted through a heat recovery silencer (EHRS) and discharged. The EXG temperature should be maintained above 150°C and preferably closer to 175°C. The district hot water (DHW) loop is circulated first through the JW plate HX where its temperature is increased by approximately 5 to 10°C and then through the EHRS for a further increase in temperature of 3 to 5°C. The resulting DWHS temperature would be in the range of 82 to 105°C.

System controls for this process, as shown in Figure 40, would be as follows:

- Exhaust gas (EXG) flow through the existing silencer and proposed EHRS is controlled by a motorized valve on each stream actuated by DHWS temperature and flow sensors (with DG interlock). Under no water flow condition in the DHW loop, the by-pass valve on the existing EXG stream opens while the recovery valve closes to divert the EXG through the existing silencer. The same sequence of operation occurs if the temperature sensor on the DHW senses a temperature above the preset point. Such temperature indicates overheating of the DHW either because the DHW flow is blocked, or because the district hot water return (DHWR) temperature is too high (too little heat extracted by the end users).

- DHW flow through the EHRS is controlled by a 3-way motorized mixing valve in order to maintain the exhaust gas discharge temperature above the dew point.

The advantages of this alternative are as follows:

- JW is looped only through the HX, therefore there is less piping and equipment which can fail and disrupt JW flow. (Potential failure of the JW cooling system cannot be tolerated.)

- HX would remove sufficient heat energy from JW so as not to require operation of the radiator and, therefore, increase overall system benefits by eliminating the electrical energy required to operate the engine radiator fan.

- There is no chance of overloading the engine radiator as only JW heat would require rejection, even on days when HX is not operated.

- Depending on the pressure drop across the HX and extra piping, a detailed analysis may reveal that the existing JW pumps may be adequate, and therefore, not require replacement. (For purposes of this study new pumps has been included.)

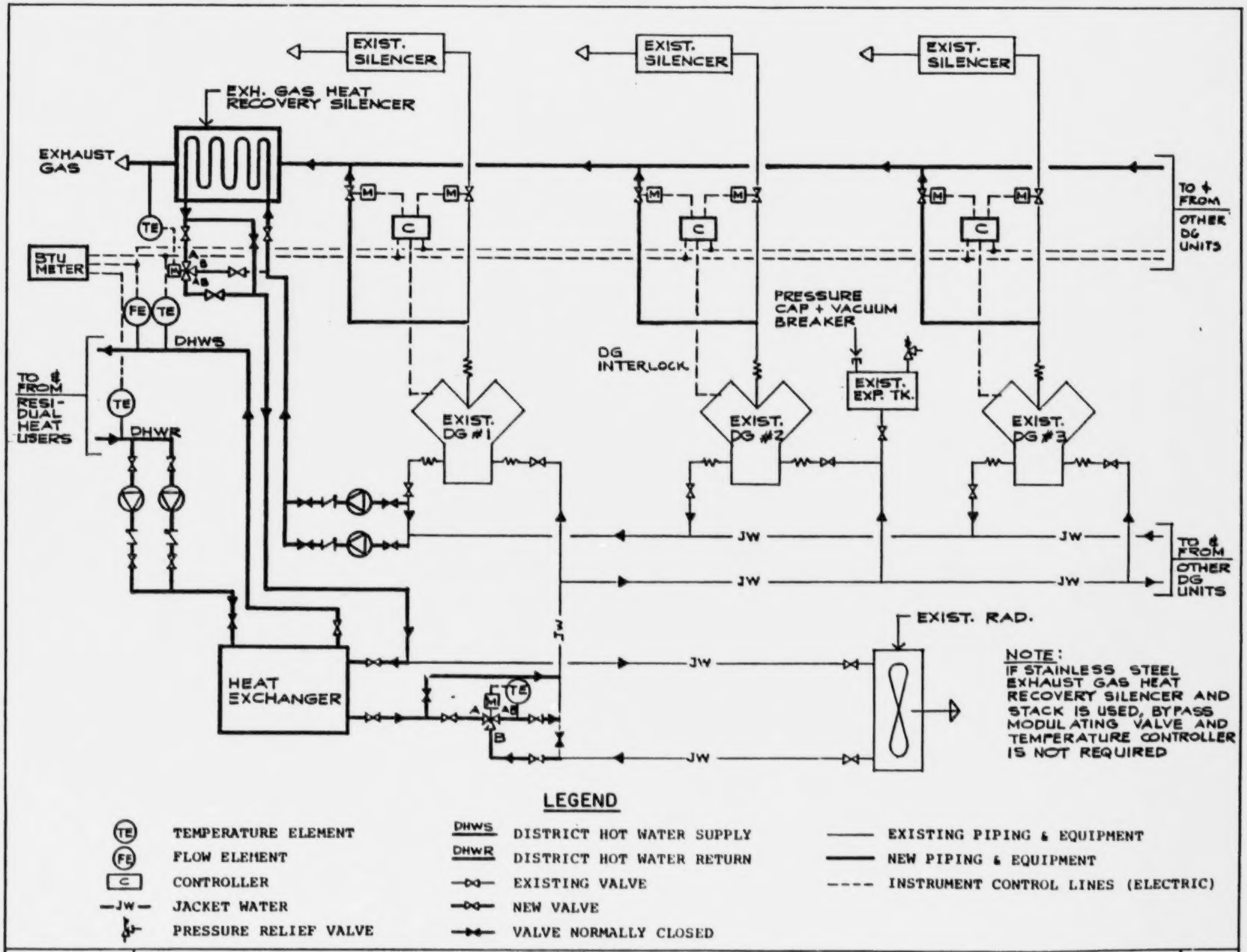
The main disadvantage of this alternative is that because of a lower temperature difference between the JW inlet temperature and the DHWR temperature, a larger HX would be required to raise the DHWR temperature.

b) Alternative 2

In the second alternative, Figure 41, JW is cycled from the DG units, through the EHRS, through the JW HX and, if additional cooling is required, through the existing engine radiator before returning to the DG units. The control sequence for this system is similar to Alternative 1.

The advantage of this alternative is as follows:

- Due to the higher temperature JW it will be possible


EXIST. SILENCER
EXIST. SILENCER
EXIST. SILENCER
EXH. GAS HEAT RECOVERY SILENCER
EXHAUST GAS
TE
BTU METER
A
B
AB
M
FE
TE
DHWS
TO & FROM RESI-DUAL HEAT USERS
TE
DHWR
M
C
M
EXIST. DG #1
M
C
M
DG INTERLOCK
EXIST. DG #2
PRESSURE CAP + VACUUM BREAKER
EXIST. EXP. TK.
M
C
M
EXIST. DG #3
TO & FROM OTHER DG UNITS
JW
JW
JW
JW
TO & FROM OTHER DG UNITS
JW
EXIST. RAD.
HEAT EXCHANGER
TE
M
A
AB
B
JW
JW

NOTE:
IF STAINLESS STEEL EXHAUST GAS HEAT RECOVERY SILENCER AND STACK IS USED, BYPASS MODULATING VALVE AND TEMPERATURE CONTROLLER IS NOT REQUIRED

LEGEND

TE TEMPERATURE ELEMENT
FE FLOW ELEMENT
C CONTROLLER
—JW— JACKET WATER
PRESSURE RELIEF VALVE
DHWS DISTRICT HOT WATER SUPPLY
DHWR DISTRICT HOT WATER RETURN
—⋈— EXISTING VALVE
—⋈— NEW VALVE
—⧓— VALVE NORMALLY CLOSED
—— EXISTING PIPING & EQUIPMENT
—— NEW PIPING & EQUIPMENT
---- INSTRUMENT CONTROL LINES (ELECTRIC)

DILLON

PROPOSED RESIDUAL HEAT RECOVERY SYSTEM
FOR NCPC PLANTS - ALTERNATIVE 2

FIG No
41

to obtain a higher DHWS temperature than with the other alternative. This is possible because the temperature of the JW entering the HX would be higher.

The disadvantages when compared to Alternative 1 are:

- Radiator cooling system could become overloaded. If HX is not operated, the extra heat picked up from the EXG must be rejected through the engine radiator.
- The higher pressure drop across the HX and the EHRS as well as through the extra piping and control valves would undoubtedly require replacement of existing JW recirculation pumps.
- Extending the JW loop would further expose a critical cooling loop to potential leakage and/or rupture. Such a failure could result in damage to the DG.

In view of the major disadvantages with Alternative 2, it was rejected from further consideration.

c) Alternative 3

This alternative would consist of extending the JW loop to distribute heat to the end users. This would eliminate the need for a HX at the NCPC plant and reduce the number of recirculating pumps required. Furthermore it would provide a higher grade of heat and thereby increase utilization of the residual heat recovered. A major disadvantage, however, is that it would increase the vulnerability of the jacket water loop to rupture and thereby increase the risk of damaging the DG's. Because of the increased potential danger to the NCPC DG units, this alternative was also rejected from further consideration.

6.4 Potential Users and Heating Load Demand

A listing of candidate sites is given in Table 8. A detailed description of each potential residual heat user, together with its respective heating load, is presented for each site in Appendix "D". The information was generated from a review of previous reports and discussions with local GNWT officers. For specific users, for which exact heating loads were unavailable, estimates were made based on the building area multiplied by an estimated rate of heat loss per square metre of floor area. The rate of heat loss was based on an assumed value of 0.19 kW/m^2 for single storey buildings in Yellowknife multiplied by the ratio of the maximum heating design temperature difference for each specific site to that for Yellowknife (for example, Yellowknife's maximum heating design temperature is 21°C - (-51.1)°C = 72°C). For buildings greater than one storey, the total heat loss was increased by 50 percent for each additional storey.

6.5 Alternative Methods For Distribution of Recovered Residual Heat

The residual heat recovered from the JW loop and/or the EXG stream can be distributed by one of the following systems:

- high temperature/high pressure (120°C+)
- medium temperature (90°C)
- low temperature (25°C).

a) High Temperature/High Pressure Distribution System

High temperature/high pressure DHW systems have been used successfully in Scandinavian countries but have not gained widespread use in other countries. In Canada, a high temperature/high pressure system has been installed in Inuvik and is presently being evaluated by another consultant under a different study. The results of that study should provide the basis with which to evaluate the feasibility of installing similar systems.

In general, the major benefit of a high temperature/high pressure DHW system is the low capital cost of the distribution hardware. This benefit results from the large difference between the DHWS and DHWR temperature of 120°C and 70°C respectively. This differential allows the use of smaller diameter distribution piping as well as smaller pumps, heat exchangers and related control valves and appurtenances.

Cost disadvantages result from the following:

- Since JW and EXG heat recovery systems will only boost DHWS temperature to 105°C, a supplementary boiler adjacent to the NCPC plant would be required to provide the additional heat to raise the DHWS temperature to 120°C.

- Because of the large temperature gradient between the outside air and DHW, these systems incur a higher rate of heat loss in the distribution piping when compared to a medium temperature (90°C) DHWS temperature for the same pipe insulation value. Additional capital cost would be spent to balance the insulation thickness against operating costs associated with the heat loss.

- Potential end users would not normally be equipped to accept high temperature/high pressure hot water and may require extensive and costly modifications to their existing heating system.
- End user boilers would still be required as standby units in the event that the distribution system was out of service.

Therefore, the benefit of lower installation costs for the distribution hardware has to be weighed against the added boiler capital and operating and maintenance cost at the NCPC plant as well as more costly modifications at the end user. General indications are that such a system may prove to be more costly than other systems and is not given further consideration.

b) Medium Temperature Distribution System

The DHWS temperature of 90°C is most widely used in Canada. This system, as presently installed in Cambridge Bay and Lac La Martre, uses standard space heating radiation units designed to provide the maximum space heating requirements, at an average supply water temperature of 76.7°C (inlet temperature of 82.2°C) and a temperature drop of 11°C across the heaters. At lower average supply water temperatures the heater capacity decreases rapidly. (For example, using Trane Company heaters, the radiation capacity, as shown in Figure

37, drops 30 to 40 percent (depending on the type of heater) over a drop in supply water temperature from 88°C to 66°C.) The advantages of a medium temperature system over a high temperature/high pressure system include the following:

- no requirement for a boiler at the NCPC plant to boost the DHWS temperature
- lower rate of heat loss in the distribution piping for the same insulation thickness and can utilize lower cost polybutylene pipe instead of carbon steel
- no requirement for end user existing radiation equipment modifications

Its disadvantages compared with the high temperature/high pressure system are as follows:

- larger diameter piping
- larger pumps and heat exchangers
- requirement for boilers at the end user facilities to raise temperature to the level required by the radiation units. (When heat recovery system is out of service or DHWS temperature is below design temperature for radiation units.)

c) Low Temperature Distribution System

The last alternative uses low temperature DHW (25 to 40°C) with a heat pump at the user facilities. The heat pump would raise the water temperature at the user end to approximately 60°C. Because most potential end users presently use conventional hot water radiators designed for 100 percent output at an average DHWS temperature of 82.2°C, additional or new radiation equipment would have to be installed.

Alternately, the low temperature system may be reasonable for heat recovery systems serving new buildings only with radiation equipment specifically designed for the lower DHWS temperature.

In any case installations serving only new buildings appear unlikely. Even for new buildings the cost of heat pumps and larger radiation units at each end user may overshadow the benefits of using residual heat. Therefore supplying hot water at low temperatures is not given further consideration.

7. COST ESTIMATES AND ECONOMIC EVALUATION

7.1 Cost of Residual Heat Recovery Systems

Capital cost estimates are based on 1985 construction and are comprised of three cost components:

- heat recovery equipment in the NCPC station
- district hot water distribution loops
- end user service connection

Two types of heat recovery systems were considered:

- jacket water heat recovery only
- jacket water plus exhaust gas heat recovery

A summary of these costs is presented in Table 10, for details refer to Appendix "E-1".

The following cost assumptions are noteworthy:

a) Heat Recovery Equipment Costs

- Jacket water plus exhaust gas heat recovery facilities were based on the concept shown in Figure 40.
- For the jacket water heat recovery only system, the following costs were excluded:
  - recovery silencer
  - bypass gas piping

TABLE 10

CAPITAL COST OF HEAT RECOVERY SYSTEM INSTALLATION

	1985 Cost of Residual Heat Recovery System Installation	
	Jacket Water Heat Recovery Only	Jacket Waterv and Exhaust Gas Heat Recovery
Aklavik	$ 307,504.00	$ 671,633.00
Arctic Bay	285,811.00	775,849.00
Arctic Red River	106,880.00	226,577.00
Baker Lake	1,220,698.00	1,715,276.00
Broughton Island	196,901.00	607,535.00
Cambridge Bay**	N/A	N/A
Cape Dorset	437,655.00	641,301.00
Chesterfield Inlet	572,190.00	670,168.00
Clyde River	765,411.00	1,216,152.00
Coppermine	609,807.00	1,208,840.00
Coral Harbour	500,291.00	772,684.00
Eskimo Point	399,356.00	1,060,860.00
Fort Franklin**	223,177.00	526,696.00
Fort Good Hope	264,970.00	607,179.00
Fort Liard	114,746.00	241,315.00
Fort McPherson	213,248.00	544,569.00
Fort Norman	223,038.00	423,511.00
Fort Simpson**	688,006.00	1,250,600.00
Gjoa Haven	525,495.00	842,999.00
Grise Fiord	212,231.00	472,118.00
Hall Beach	323,331.00	507,374.00
Holman Island	468,799.00	436,687.00
Igloolik**	196,469.00	739,335.00
Jean Marie River	N/A	N/A
Lac La Martre (Actual)	N/A	249,000.00*
Lac La Martre (Calculated)**	N/A	254,000.00
Lake Harbour	146,451.00	410,711.00
Nahanni Butte	72,760.00	125,416.00
Pangnirtung	261,375.00	964,578.00
Paulatuk	77,398.00	230,378.00
Pelly Bay**	146,857.00	396,850.00
Pond Inlet	718,585.00	1,271,996.00
Rae Lakes	73,551.00	134,380.00
Rankin Inlet**	444,564.00	1,854,452.00
Repulse Bay	272,190.00	567,240.00
Sachs Harbour	235,897.00	518,316.00
Snowdrift	166,664.00	268,974.00
Spence Bay	315,508.00	697,764.00
Whale Cove	190,334.00	387,724.00
Wrigley	79,244.00	299,449.00

* For Lac La Martre, the calculated and actual capital costs (1983) are shown. Note actual 1983 cost of $249,000 vs 1985 calculated cost of $254,000.

** Sites presently equipped with partial heat recovery/distribution systems. Costs based on 100% new systems.

  - related motorized valves
  - sensors
  - extra water loop piping

- No allowances were made for re-using existing heat recovery/distribution equipment and piping at those sites presently equipped with partial heat recovery systems.

b) District Hot Water Distribution Loop

- For computing capital cost of distribution of DHW to end users, piping runs as shown in Figures D1 to D39 of Appendix "D" were used.

c) End User Service Connection Costs

- Capital costs for valves, controls, pumps and piping have been included for the concept shown in Figure 39, Alternative 1.

- Due to lack of detailed information at each end user facility, it was assumed that hot water would be used directly for heating. (For specific users equipped with a forced air heating system, capital costs would be approximately 8 percent higher to cover retrofit costs for an air/water heat exchanger.)

- Costs are based on using a DHWS temperature of 82°C. (If DHW is to be used directly at a delivered temperature below the required 82°C without reheating, then the existing radiation capacity would be insufficient.

Additional radiators would be required. Since these costs should not be a major item (compared to modifications at the NCPC plants or the DHW piping to the users) and since calculation of these costs is dependent on the DHWS temperature at each site (an unknown at this time), they have not been included in this report. However, allowances should be made at the preliminary design stage for any community residual heat recovery system which may not be capable of delivering a DHWS temperature of 82°C.)

7.2 Energy Cost Savings

Energy cost savings for each site have been calculated and presented in Table 11. These costs are based on the following assumptions:

- Energy savings from jacket water heat recovery only:
  - at the average utilization rate calculated for Cambridge Bay over the monitoring period - 45 percent utilization.
  - at full utilization (100 percent) of the recoverable residual heat (calculated from the forecast average electrical load for 1985-86 and NCPC's load factor).

TABLE 11

ANNUAL ENERGY COST SAVINGS

	Annual Energy Cost Savings			
	Jacket Water Heat Recovery Only		Jacket Water and Exhaust Heat Recovery	
	45% Utilization[1]	100% Utilization	55% Utilization[2]	100% Utilization
Aklavik	$ 24,677.33	$ 54,838.52	$ 49,354.67	$ 89,735.76
Arctic Bay	18,119.23	40,264.96	36,238.47	65,888.12
Arctic Red River	3,783.41	8,407.58	7,566.82	13,757.86
Baker Lake	53,405.98	118,679.96	106,811.97	194,203.58
Broughton Island	13,798.35	30,663.01	27,596.71	50,175.83
Cambridge Bay	89,007.69	197,794.86	178,015.37	323,664.31
Cape Dorset	30,857.11	68,571.36	61,714.23	112,207.69
Chesterfield Inlet	9,908.28	22,018.40	19,816.56	36,030.11
Clyde River	20,222.07	44,937.94	40,444.15	73,534.82
Coppermine	36,868.47	81,929.92	73,736.93	134,067.15
Coral Harbour	32,954.40	73,232.01	65,908.81	119,834.29
Eskimo Point	28,789.31	63,976.25	57,578.62	104,688.41
Fort Franklin	15,378.89	34,175.31	30,757.78	55,923.24
Fort Good Hope	10,801.62	24,003.61	21,603.25	39,278.63
Fort Liard	5,727.94	12,728.75	11,455.88	20,828.86
Fort McPherson	20,500.21	45,556.02	41,000 42	74,546.21
Fort Norman	9,854.93	21,899.85	19,709.87	35,836.12
Fort Simpson	37,701.21	83,780.47	75,402.42	137,095.32
Gjoa Haven	28,470.11	63,266.90	56,940.21	103,527.66
Grise Fiord	7,613.32	16,918.48	15,226.63	27,684.79
Hall Beach	15,392.62	34,205.82	30,785.24	55,973.16
Holman Island	15,560.83	34,579.62	31,121.66	56,584.83
Igloolik	32,640.82	72,535.15	65,281.63	118,693.88
Jean Marie River	499.19	1,109.31	998.38	1,815.24
Lac La Martre	6,249.57	13,887.93	12,499.14	22,725.71
Lake Harbour	11,855.70	16,345.99	23,711.39	43,111.62
Nahanni Butte	1,236.29	2,747.32	2,472.58	4,495.61
Pangnirtung	26,884.04	59,742.31	53,768.08	97,760.15
Paulatuk	7,031.22	15,624.94	14,062.45	25,568.09
Pelly Bay	17,638.48	39,196.63	35,276.97	64,139.94
Pond Inlet	38,775.53	86,167.83	77,551.05	141,001.91
Rae Lakes	4,077.52	9,061.16	8,155.05	14,827.36
Rankin Inlet	72,548.04	161,217.87	145,096.08	263,811.05
Repulse Bay	11,771.34	26,158.53	23,542.68	42,804.87
Sachs Harbour	17,086.32	37,969.59	34,172.64	62,132.06
Snowdrift	4,085.86	9,079.70	8,171.73	14,857.68
Spence Bay	33,414.76	74,255.03	66,829.53	121,508.23
Whale Cove	9,087.17	20,193.72	18,174.35	33,044.27
Wrigley	3,263.52	7,252.27	6,527.04	11,867.34

Notes:

1. Monitored utilization rate at Cambridge Bay.
2. Monitored utilization rate at Lac La Martre.

- Energy savings from both the jacket cooling water and exhaust gas heat recovery:
    - at the average utilization rate calculated for Lac La Martre over the period 24 January to 5 February - 55 percent
    - at full utilization (100 percent) of the recoverable residual heat (calculated from the forecast average electrical load for 1985-86 and NCPC's load factor).
- Using Arctic No. 2 fuel oil (for space heating) having a calorific value of 9.76 kW.h/L.
- Fuel oil cost for space heating based on fuel cost table in Appendix "E-2".
- Annual energy cost savings calculated by using ASHRAE's modified Degree Day formula to calculate fuel oil consumption for space heating and multiplying it by the cost of fuel oil.
- Degree days taken from Environment Canada Canadian Climate Normals - Volume 4 Degree Days 1951-1980.
- Fuel costs are 1984-5 prices. (Note that prices may be higher for the 1985-86 forecast year. Recent information, however, indicates that the 1985-86 cost of fuel oil for Lac La Martre has dropped to $0.54/L as compared to $0.56/L in 1984-85 and $0.58/L in 1983-84.)

7.3 Economic Evaluation

The cost effectiveness of installation of heat recovery equipment for all candidate sites was based on the payback period, i.e. the number of years it would take to payback the capital investment from savings in fuel costs less the maintenance and operating costs of the heat recovery equipment. The calculations are called "simple" payback, since no allowance was made for the time value of money.

The following formula was used for these calculations:

$$\begin{array}{l}\text{SIMPLE PAYBACK}\\ \text{OF HEAT}\\ \text{RECOVERY EQUIP-}\\ \text{MENT IN YEARS}\end{array} = \frac{\text{TOTAL CAPITAL COST}}{\text{ANNUAL SAVINGS (FUEL SAVINGS - O \& M COSTS)}}$$

If future years savings and costs are discounted to allow for the time value of money, longer payback periods would result. The impact of this type of analysis would be more pronounced for facilities with long payback periods than for short simple paybacks. (For example, a simple payback period of 3 years would be increased by approximately half a year at a discount rate of 8 percent.)

Capital costs and annual energy savings were taken from Table 10 and Table 11 respectively. Various available heat utilization rates were used to demonstrate the sensitivity on payback period and the probable range which could be expected.

Annual maintenance costs were calculated as 2 percent of the heat recovery equipment capital costs as reported by NCPC.

The annual operating costs were based on operating the recirculation pumps for approximately 8 months each year at a base cost of $0.679/kWh of electrical energy.

The results from the economic evaluation, in order of simple payback period, are presented in Tables 12 to 15 and detailed in Appendix "E-3".

TABLE 12

COST EVALUATION FOR JACKET WATER HEAT RECOVERY AT 45% UTILIZATION

	Pay Back Period (Years)
Rankin Inlet	7.15
Igloolik	8.58
Pelly Bay	12.45
Spence Bay	14.88
Paulatuk	15.12
Pangnirtung	16.49
Fort McPherson	20.48
Lake Harbour	24.31
Aklavik	24.36
Sachs Harbour	24.92
Cape Dorset	27.02
Broughton Island	28.30
Eskimo Point	33.10
Coral Harbour	35.20
Arctic Bay	35.57
Coppermine	38.27
Pond Inlet	38.63
Rae Lakes	39.15
Gjoa Haven	43.30
Fort Franklin	43.83
Fort Simpson	45.25
Baker Lake	60.26
Hall Beach	70.94
Repulse Bay	79.46
Whale Cove	79.99
Wrigley	83.36
Fort Norman	89.50
Fort Good Hope	101.90
Fort Liard	216.09
Holman	258.03
Grise Fiord	454.75
Arctic Red River	563.08
Clyde River	-840.98[1]
Snowdrift	-236.93[1]
Chesterfield Inlet	-128.94[1]
Nahanni Butte	-124.82[1]
Jean Marie River	NA[2]
Cambridge Bay	NA[2]
Lac La Martre	NA[2]

[1] Negative pay back period indicates that annual O&M costs exceed the annual fuel cost savings.

[2] Pay back periods for these sites was not calculated. For Jean Marie River there was insufficient heat available for district heating use. For Lac La Martre and Cambridge Bay, systems are already in place.

TABLE 13

COST EVALUATION FOR JACKET WATER HEAT RECOVERY AT 100% UTILIZATION

	Pay Back Period (Years)
Rankin Inlet	2.95
Igloolik	3.13
Pelly Bay	4.40
Spence Bay	5.09
Pangnirtung	5.37
Paulatuk	5.64
Fort McPherson	6.01
Lake Harbour	7.14
Aklavik	7.19
Sachs Harbour	7.77
Cape Dorset	8.12
Broughton Island	8.27
Eskimo Point	8.45
Coral Harbour	9.18
Fort Franklin	9.34
Arctic Bay	9.47
Coppermine	10.00
Rae Lakes	10.72
Pond Inlet	10.89
Gjoa Haven	11.20
Fort Simpson	11.23
Hall Beach	13.83
Whale Cove	14.11
Baker Lake	14.27
Fort Liard	15.23
Repulse Bay	15.28
Fort Norman	15.34
Wrigley	16.04
Fort Good Hope	16.77
Grise Fiord	21.72
Arctic Red River	22.20
Holman	22.50
Clyde River	32.15
Snowdrift	38.85
Chesterfield Inlet	74.58
Nahanni Butte	78.40
Cambridge Bay	NA[1]
Jean Marie River	NA[1]
Lac La Martre	NA[1]

[1] Pay back periods were not calculated for these sites. For Jean Marie River there was insufficient heat available for district heating use. For Lac La Martre and Cambridge Bay, systems are already in place.

TABLE 14

COST EVALUATION FOR JACKET WATER AND EXHAUST GAS HEAT RECOVERY AT 55% UTILIZATION

	Pay Back Period (Years)
Rankin Inlet	10.00
Lac La Martre (Actual)[1]	13.81
Spence Bay	15.81
Cape Dorset	15.97
Pelly Bay	17.28
Igloolik	17.70
Coral harbour	18.52
Aklavik	24.71
Fort McPherson	25.48
Holman	26.33
Paulatuk	26.40
Sachs Harbour	26.66
Gjoa Haven	26.89
Pond Inlet	29.33
Baker Lake	29.60
Coppermine	29.61
Rae Lakes	33.50
Hall Beach	34.20
Fort Simpson	34.90
Fort Franklin	36.58
Lake Harbour	36.90
Pangnirtung	37.47
Eskimo Point	48.66
Whale Cove	51.57
Arctic Bay	52.08
Lac La Martre (Theoretical)[1]	56.23
Fort Norman	61.63
Broughton Island	63.01
Repulse Bay	72.45
Fort Liard	106.70
Clyde River	118.11
Fort Good Hope	119.25
Grise Fiord	163.80
Snowdrift	201.29
Chesterfield Inlet	327.68
Arctic Red River	1,699.96
Wrigley	-326.22[2]
Nahanni Butte	-164.21[2]
Jean Marie River	N/A[3]
Cambridge Bay	N/A[3]

[1] Actual represents figures from "as-constructed" system. Theoretical represents figures calculated based on the same estimating techniques used for all other sites.

[2] Negative pay back period indicates that annual O&M costs exceed the annual fuel cost savings.

[3] Pay back periods for these sites was not calculated. For Jean Marie River there was insufficient heat available for district heating use. For Lac La Martre and Cambridge Bay, systems are already in place.

TABLE 15

COST EVALUATION FOR JACKET WATER AND EXHAUST GAS HEAT RECOVERY AT 100% UTILIZATION

	Pay Back Period (Years)
Rankin Inlet	5.00
Spence Bay	7.06
Cape Dorset	7.07
Pelly Bay	7.66
Igloolik	7.77
Coral Harbour	8.08
Fort McPherson	9.92
Aklavik	9.94
Holman	10.39
Gjoa Haven	10.82
Sachs Harbour	10.94
Paulatuk	11.39
Baker Lake	11.80
Pond Inlet	11.91
Coppermine	11.95
Rae Lakes	12.58
Hall Beach	12.68
Fort Simpson	12.82
Fort Franklin	13.31
Lake Harbour	13.45
Lac La Martre (Actual)[1]	13.81
Pangnirtung	13.83
Eskimo Point	15.39
Lac La Martre (Theoretical)[1]	17.23
Whale Cove	17.32
Arctic Bay	17.42
Fort Norman	18.42
Broughton Island	18.86
Fort Liard	20.74
Repulse Bay	20.94
Fort Good Hope	26.67
Clyde River	28.03
Grise Fiord	30.78
Snowdrift	33.53
Arctic Red River	35.83
Chesterfield Inlet	36.70
Wrigley	67.71
Nahanni Butte	99.59
Cambridge Bay	NA[2]
Jean Marie River	NA[2]

[1] Actual represents figures from "as-constructed" system. Theoretical represents figures calculated based on the same estimating techniques used for all other sites.

[2] Pay back periods for these sites was not calculated. For Jean Marie River there was insufficient heat available for district heating use. For Lac La Martre and Cambridge Bay, systems are already in place.

8. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

8.1 Findings

The following findings are highlighted from our study:

a) Cambridge Bay

.1 Jacket water (JW) inlet temperature to the diesel generator (DG) units is well regulated at a relatively constant temperature of 74°C in accordance with the manufacturer's specifications.

.2 The rise in JW temperature across the DG unit ranges from 7 to 10°C compared to the design temperture of 8.3°C.

.3 Exhaust gas (EXG) stack temperature varies directly with load.

.4 District hot water supply (DHWS) temperature is generally below 71°C but occasional peaks up to 75°C occur. This temperature is too low for utilization at the water treatment plant (WTP) where controls (three-way motorized mixing valve) have been set to accept DHWS at 71°C+. When DHWS temperature is suitable for use, the mixing valve throttles the flow thereby not taking full advantage of all available heat.

.5 Average day demand was approximately 550 kW or 62 percent of the rated output from one Caterpillar D399 DG Unit. Minimum load demand was constantly above 50 percent.

.6 Available JW and EXG heat averaged approximately 1.1 kW/kW and 0.7 kW/kW of electrical demand respectively at less than full load and compares with the manufacturer's specifications of 1.0 and 0.65 kW/kW respectively at full load.

.7 Average JW heat utilized was 45 percent. Utilization varied directly with the DHWS temperature.

.8 Manual switchover to DHWS heating in the GNWT buildings is subject to operator attention and a reversal of heat flow could occur if the DHWS temperature dips too low.

b) Lac La Martre

.9 JW inlet temperature is not firmly regulated and ranges between 65 to 75°C compared to the specified range of 74 to 91°C.

.10 The rise in JW temperature across the DG units ranged between 6 to 9°C for DG No. 3 and 11 to 15°C for DG No. 1.

.11 EXG stack temperature varies directly with load.

.12 Temperature of exhaust gas discharging from heat recovery silencer (EHRS) was frequently below 134°C, increasing the probability of corrosion.

.13 DHWS temperature is generally maintained below 70°C and compares with the design outlet temperature from the heat exchanger (HX) of 71.1°C. Temperature difference between JW inlet to, and DHWS outlet from, the HX ranges from 14 to 17°C compared with a design temperature difference of 14°C.

.14 Instantaneous electrical load ranges from 25 to 50 percent when DG Unit No. 1 is operated. Load ranges from 40 to 75 percent when DG Unit No. 3 is operated. Average day electrical load over the monitored period ranged from 60 to 80 kW.

.15 Available JW heat for DG No. 3 averaged 1.4 kW/kW (or, on an adjusted basis, 0.8-0.9 kW/kW) of electrical load, while available EXG heat showed an average ratio of 0.7 kW/kW. For DG No. 1, average JW heat ranged from 4.0 to 6.0 kW/kW (2.4-3.6 kW/kW adjusted), and EXG heat from 3.0 to 3.5 kW/kW of electrical load respectively. The higher ratios from DG No. 1 can be explained by its lower efficiencies for any given load.

.16 Average heat utilized was 55 percent. Utilization varied directly with the DHWS temperature.

c) General

.17 Medium temperature hot water (82 to 93°C) is the most feasible option to use for district heating purposes.

.18 If a JW heat recovery system was to be installed, based on 100 percent utilization of the available heat, the following candidate sites were found to have simple payback periods of less than 20 years.

Site	Pay Back Period (Years)
Rankin Inlet	2.95
Igloolik	3.13
Pelly Bay	4.40
Spence Bay	5.09
Pangnirtung	5.37
Paulatuk	5.64
Fort McPherson	6.01
Lake Harbour	7.14
Aklavik	7.19
Sachs Harbour	7.77
Cape Dorset	8.12
Broughton Island	8.27
Eskimo Point	8.45
Coral Harbour	9.18
Fort Franklin	9.34
Arctic Bay	9.47
Coppermine	10.00
Rae Lakes	10.72
Pond Inlet	10.89
Gjoa Haven	11.20
Fort Simpson	11.23
Hall Beach	13.83
Whale Cove	14.11
Baker Lake	14.27
Fort Liard	15.23
Repulse Bay	15.28
Fort Norman	15.34
Wrigley	16.04
Fort Good Hope	16.77

.19 If a JW and EXG heat recovery system was to be installed, based on a 100 percent utilization of the available heat, the following sites would have a simple payback period of less than 20 years.

Site	Pay Back Period (Years)
Rankin Inlet	5.00
Spence Bay	7.06
Cape Dorset	7.07
Pelly Bay	7.66
Igloolik	7.77
Coral Harbour	8.08
Fort McPherson	9.92
Aklavik	9.94
Holman	10.39
Gjoa Haven	10.82
Sachs Harbour	10.94
Paulatuk	11.39
Baker Lake	11.80
Pond Inlet	11.91
Coppermine	11.95
Rae Lakes	12.58
Hall Beach	12.68
Fort Simpson	12.82
Fort Franklin	13.31
Lake Harbour	13.45
Pangnirtung	13.83
Eskimo Point	15.39
Lac La Martre (Calculated)	17.23
Whale Cove	17.32
Arctic Bay	17.42
Fort Norman	18.42
Broughton Island	18.86

.20 If a JW heat recovery system was to be installed, based on a heat utilization rate of 45 percent (as monitored at Cambridge Bay), the following candidate sites would have a simple payback period of less than 20 years.

Site	Pay Back Period (Years)
Rankin Inlet	7.15
Igloolik	8.58
Pelly Bay	12.45
Spence Bay	14.88
Paulatuk	15.12
Pangnirtung	16.49

.21 If a JW and EXG heat recovery system was to be installed, based on a heat utilization rate of 55 percent (as monitored at Lac La Martre), the following sites would have a simple payback period of less than 20 years.

Site	Pay Back Period (Years)
Rankin Inlet	10.00
Lac La Martre (Actual)	13.81
Spence Bay	15.81
Cape Dorset	15.97
Pelly Bay	17.28
Igloolik	17.70
Coral Harbour	18.52

.22 There is no established maintenance program for the heat recovery equipment. Furthermore, responsibility for such maintenance is unclear. NCPC holds that their responsibility ends at the primary flanges of the JW connection to the HX.

.23 Installed generating capacity at each NCPC station is generally 2 times greater than the peak forecast electrical load.

8.2 Conclusions

On the basis of our findings, the following can be concluded:

a) Specific to Cambridge Bay

.1 The diesel generator units at Cambridge Bay appear to be operating efficiently.

.2 The three-way motorized mixing valve at the water treatment plant appears to be inappropriate for the intended service.

b) Specific to Lac La Martre

.3 Jacket water inlet temperatures below 74°C could induce thermal stresses on the diesel generator unit and cause premature failure.

.4 The low stack temperature together with the high rates of available heat from Lac La Martre indicate that the diesel generator units are not operating at optimum thermal efficiency.

.5 At less than 50 percent load, diesel generator unit No. 1 at Lac La Martre is very inefficient. Consequently most of the fuel energy input is converted to waste heat. Heat balance for diesel engines shows that up to 60 percent more waste heat is rejected to the exhaust gas stream at 25 percent load when compared to heat rejection at 100 percent load.

c) General

.6 Exhaust gas temperatures below the dew point (134°C) will condense and result in corrosion of the stack and related equipment.

.7 District hot water supply temperature is below optimum for efficient utilization by conventional space heating radiation units.

.8 Manual switchover systems should be replaced in order to optimize heat utilization and prevent reversal of heat flow.

.9 Heat recovery and distribution systems can be designed on the basis of 1.1 kW of jacket water and 0.70 kW of exhaust heat available per kW of electrical load.

.10 Heat recovery for district heating purposes appears to be a viable option for a number of candidate sites based on simple payback period calculations. In most cases, shorter payback periods exist for the jacket water only heat recovery option versus the jacket water and exhaust gas heat recovery option.

.11 Lack of a maintenance schedule and division of responsibility will result in premature failure of the heat recovery system equipment as well as reduced operating efficiency.

.12 Because less than half of the installed generating capacity is normally used, even under peak loads, installing separate heat recovery equipment on each DG unit would be very costly and most of this equipment would seldom be used.

8.3 Recommendations

a) Specific to Cambridge Bay

.1 Replace existing heat exchangers with a unit designed to provide a district hot water supply temperature within 5°C of jacket water temperature. Attempts should also be made to increase the jacket water inlet temperature to the heat exchanger to at least 85°C.

.2 Replace manual switchover system on the district hot water loop at the GNWT buildings with 3-way motorized diverter valves as per Figure 39, Alternative 1.

.3 Replace the three-way mixing valve at the water treatment plant with 3-way motorized diverting valve. Before doing this however attempts should be made to modify existing valve and controller to give similar action as a diverting valve.

b) Specific to Lac La Martre

.4 Upgrade controls to maintain the jacket water inlet temperature to the diesel engine within the specified range of 74 to 91°C. Maintain the jacket water temperature at the higher end of the range as it would result in a higher district hot water supply temperature and therefore optimize heat transfer at the end users' facility.

.5 Upgrade existing heat exchanger by installing additional plates to provide 5°C approach temperature. Concurrently, raise the jacket water inlet temperature to the heat exchanger to about 85°C.

.6 Install controls on the exhaust gas heat recovery system to maintain the exhaust temperature in the 150 to 175°C range to prevent condensation. Alternately, replace existing waste heat recovery silencer and related stack with stainless steel components.

.7 Overhaul diesel generator units to improve thermal efficiency and whenever possible use diesel generator No. 3 only, since it is more closely rated to the load and thereby provides considerably higher thermal efficiency than diesel generator No. 1.

c) General

.8 Design heat recovery systems based on 0.9 - 1.1 kW of jacket water and 0.65 - 0.70 kW of exhaust gas heat per kW of electrical load. The higher values are appropriate at low average load factors.

.9 If agreement can be reached with the end users, proceed with installation of jacket water heat recovery systems at the candidate sites having short payback periods.

.10 A scheduled maintenance program and operating responsibility for the heat recovery equipment should be established. The responsibility split should be clearly defined and agreed between NCPC and the end user.

.11 Install jacket water and exhaust gas heat recovery equipment in a manifold arrangement or only on those diesel generator units most frequently used. Do not install heat recovery equipment on diesel generator units designated standby.

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11. Design Guidelines for Continuous Duty Standby Systems, Eugene Gore & Salim Qureshi, Heating Piping & Air Conditioning - September 1977.

APPENDIX "A"

NWT DIESEL-ELECTRIC RESIDUAL HEAT RECOVERY STUDY

TERMS OF REFERENCE

Introduction:

The G.N.W.T. has an agreement with the Northern Canada Power Commission, whereby the Government has first rights to the residual heat at all NCPC diesel powerplants. Under this agreement, the G.N.W.T. is responsible for all the capital costs associated with collecting and distributing the residual heat and for all subsequent operating and maintenance costs. This includes any modifications or additions to the diesel generating equipment within the powerplant. There are no other fees applied.

Presently, the G.N.W.T. is utilizing residual heat at five locations in the NWT and a sixth installation is under construction at the G.N.W.T. owned and operated powerplant at Sanikiluaq.

It is the intent of the G.N.W.T. to increase the use of this resource at other sites and to maximize the economic benefits of both the existing and any new installations.

Study Objectives:

A. Obtain and analyze information to establish the viability of recovering residual heat from the NCPC diesel-electric generating plant in each N.W.T. community, in accordance with the attached list (Appendix 'A').

B. To assemble construction and performance data for existing heat recovery installations.

C. To analyze methods and equipment with the intent of optimizing the heat recovery process.

Scope of Work:

1. The study shall be conducted in accordance with these terms of reference prepared by the Study Management Committee. Committee members are:

MEMBERS	AGENCY REPRESENTED	PHONE NO.
Les Clegg Chairman	D.P.W. & Highways G.N.W.T.	873-7397
Ron Hawkins	D.P.W. & Highways G.N.W.T.	873-7203
Jim Cumming	CREO, Yellowknife Energy, Mines & Resources	920-8475
Ron Walton	CREO, Yellowknife Energy, Mines & Resources	920-8560
Vern Christensen	Dept. of Local Government G.N.W.T.	873-7135
Philip Johnson	Northern Canada Power Commission, Yellowknife	873-4051

Contact persons for additional information and details are:

Philip Johnson	Northern Canada Power Commission	
Vern Christensen	G.N.W.T.	
Brian Lemax	Engineering, D.P.W.&H., G.N.W.T.	7828

2. The Study Management Committee shall review and advise on any redirection or curtailment of work, milestones and reports appropriate for a payment schedule; and distribution and assessment of draft and final report.

3. The consultant may submit a schedule of payment as part of the proposal. The committee will consider part payments of no less than 25% of consultant's contract. Payment will not exceed 50% of total contract prior to receipt of complete draft report.

4. SPECIFIC TASKS

TASK A. - Obtain and analyze information to establish the viability of recovering residual heat from the NCPC diesel-electric generating plant in each N.W.T. community, in accordance with the attached list (Appendix 'A').

(i) Through discussions with N.C.P.C., senior personnel determine the operating characteristics and limitations of each of the N.C.P.C. diesel electric generating plants listed in Appendix A. This will include obtaining power generation records, the estimated growth of power demand, any plans for expansion or modification to plant and N.C.P.C.'s requirements for installation of heat recovery equipment and their views on feasibility and appropriateness of installing heat recovery equipment in each of the plants.

(ii) Evaluate the potential uses for recovered residual heat considering location, size, construction type, use and estimated or actual heat load of all buildings relative to the generating plant or any new large buildings (such as schools, community halls) planned for each location. Data can be obtained through research of information available from the Government of the Northwest Territories (H.Q. and Regional Offices), Municipal Governments and other building owners.

(iii) Use the electrical generation statistics provided by N.C.P.C. to estimate the average amount and temperature of residual heat available at each location for each month of the year.

(iv) Develop concepts for the recovery and use of residual heat which may include the following:

- use of jacket water heat alone to heat buildings, fuel storage, water supply or distribution systems, etc.
- use of jacket heat and exhaust heat together to accomplish the above.
- determine the amount of residual heat which each alternative would recover.

(v) Estimate, in conjunction with N.C.P.C. and building owners the capital cost of renovations required to incorporate the heat recovery equipment in the plant, the distribution system required and the alterations required within the buildings to be heated for each alternative. Include the cost of design and an allowance for administration of the contract to install the equipment. (All estimates should be provided in enough detail to be able to assess the sensitivity of variables such as number of generators installed, length of distribution mains, number of buildings using heat etc. on the cost of the system.)

(vi) Assess the cost effectiveness of each alternative on a 20 year life cycle cost in consideration of all capital operating and maintenance costs. Group the above into 5, 10 and 15 year pay back projects and priorize within those groups.

TASK B - To assemble construction and performance data for existing heat recovery installations.

(i) Collect information from Lac La Martre (exhaust and jacket recovery) and Cambridge Bay (jacket recovery) heat recovery installations over a period of two months in order to carry out a full assessment of the heat recovery process. Information collected should include continuous readings of at least the following data:

- electrical load for each generator in operation.
- coolant temperatures (in and out) on the heat exchanger primary and secondary sides.
- outside air temperature, was this to remain?
- exhaust boiler fluid temperatures (in and out)
- exhaust gas temperatures (before and after boiler).
- heat distribution mains temperatures (supply and return) at the loads.
- flows in the distribution mains.
- building internal heating system temperatures (supply and return).
- building daily fuel consumption.
- any other readings available, temperature, B.t.u., flow or other meters on the system.

The consultant should note that monitoring equipment is not necessarily installed and that some equipment may be available on a loan basis from the G.N.W.T. or N.C.P.C.

(ii) Assemble all data available for the other heat recovery installations (3) at N.C.P.C. plants in the N.W.T. as identified in Appendix A. Igloolik, Pelly Bay, Rankin Inlet.

(iii) Determine the proportion of waste heat available for recovery from the 5 existing installations that has not been utilized and provide this information on a yearly basis summarized by month.

(iv) Assemble a historical record of existing installations including operating and maintenance costs, equipment failures and replacements and downtime. An overall assessment of the performance of the system in terms of cost savings, utilization of available residual heat and any other direct or indirect benefits that may have materialized.

NOTE: The original heat recovery system at Igloolik has been recently upgraded because of a major failure. Report is to cover both the original and the renovated system.

(v) An assessment of the remaining useful life and potential for upgrading and renovation to extend the life and reduce operating and maintenance costs.

TASK C - To analyze methods and equipment with the intent of optimizing the heat recovery process.

(i) Utilize the date gathered during the monitoring program, the information provided by N.C.P.C., Government of N.W.T. and any other sources available to the consultant to analyze and report on the following factors as they relate to utilizing residual heat from N.C.P.C. diesel electric generating plants in the N.W.T:

- fluctuations in electric load in relation to outside temperature, time of day, amount of daylight.
- effect of changes in heating load on the efficiency of heat exchangers.
- methods, if any, to achieve optimum balance between electrical load and heating load.
- the optimum system operating temperatures for recovering residual heat, such that there is no harm to the diesel engine and no loss in generating efficiency.
- costs of providing heat to a single large user vs several small users.
- impact of using residual heat on building construction, operating and maintenance costs.
- optimum temperature of heating fluid in referance to size of pipe, heat exchanger, heaters, and pumps and insulation values.

- optimum combination of heat exchangers at the the plant in relation to heat required in the buildings supplied with heat.
- costs of retrofitting existing buildings to utilize the recovered heat vs. providing the heat to new buildings.

(ii) An evaluation of potential schemes to enhance the utilization of residual heat. An example is the use of boilers to handle peak heating loads in order to fully utilize all available residual heat.

5. REPORT:

Complete documentation of all methods used, results gathered, substantiation of analysis performed and conclusions reached must be provided. Computer printouts of the results alone will not be considered acceptable.

Progress reports shall be provided in accordance with a schedule to be established when the consultant has met with the Study Management Committee (approximately November 15, 1984).

A final report shall be presented in draft form to the committee for comments. The final report shall take into account comments provided by the committee and shall include as a minimum: executive summary, table of contents, introduction, technical and economic discussion, supporting tables, graphs and charts as appropriate, conclusions, recommendations, and bibliography or references.

Two original unbound reproducible versions and six copies of the final report shall be given to the committee.

Invoices shall be forwarded to the Energy Conservation Division, Department of Public Works and Highways, Government of the Northwest Territories, Yellowknife. G.N.W.T. forms "Request for Contract Payment" will be used for this purpose. Accompanying documentation shall show the time worked by each individual, his or her rate and position. All disbursements shall be supported by vouchers and be in accordance with Treasury Board Guidelines.

Dates for further meetings to guide and determine progress will be established between the committee and the consultant at the meeting proposed for November 15, 1984 in Yellowknife. The consultant should anticipate at least one additional progress review meeting with the committee prior to submission of the final report.

6. OTHER INFORMATION:

The following publications will be provided to the successful proponent:

a) "Evaluation of Waste Heat Recovery Potential at Selected Diesel Stations in the Northwest Territories"
Ferguson, Naylor, Simek Ltd., July 1980.

b) "An Inventory of Major Diesel Generating Systems In Canada and an Assessment of the Potential Markets for Heat Recovery"
Ferguson, Naylor, Simek Ltd. , (Vol. 1 & 2) 1981.

c) "Heat Recovery Retrofit Project, Lac La Martre School, Northwest Territories"
Ferguson, Simek, Clark Ltd., August 1983.

d) "Fort Providence Waste Heat Recovery"
Ferguson, Simek, Clark Ltd.

e) As-built N.C.P.C. plant drawings for existing installations.

Also an additional
report on RHR
potential (also FSC).

NWT DIESEL ELECTRIC RESIDUAL HEAT RECOVERY STUDY

LOCATION	A) EXISTING INSTALLATION EFFICIENCY TO BE MONITORED	B) EXISTING INSTALLATION CAPACITY VS NOW BEING RECOVERED COMPARISON	C) SUGGESTED FIRST PREFERENCE TO PLAN RECOVERY 5 YEAR OR LESS PAYBACK	D) SUGGESTED SECOND PREFERENCE TO PLAN RECOVERY. MORE THAN 5, LESS THAN 10 YEAR PAYBACK	E) FUTURE POTENTIAL TO PLAN RECOVERY	F) DOUBTFUL OR LEAST LIKELY. TO BE VIABLE UNDER EXISTING CIRCUMSTANCES
AKLAVIK			✓			
ARCTIC BAY			✓			
ARCTIC RED RIVER					✓	
BAKER LAKE				✓		
BROUGHTON ISLAND				✓		
CAMBRIDGE BAY	✓	✓				
CAPE DORSET			✓			
CHESTERFIELD INLET			✓			
CLYDE RIVER					✓	
COPPERMINE			✓			
CORAL HARBOUR			✓			
ESKIMO POINT				✓		
FORT FRANKLIN			✓			
FORT GOOD HOPE			✓			
FORT LIARD				✓		
FORT MCPHERSON				✓		
FORT NORMAN			✓			
FORT SIMPSON		✓	✓			
GJOA HAVEN				✓		

LOCATION	A) EXISTING INSTALLATION EFFICENCY TO BE MONITORED	B) EXISTING INSTALLATION CAPACITY VS NOW BEING RECOVERED COMPARISON	C) SUGGESTED FIRST PREFERENCE TO PLAN RECOVERY 5 YEAR OR LESS PAYBACK	D) SUGGESTED SECOND PREFERENCE TO PLAN RECOVERY. MORE THAN 5, LESS THAN 10 YEAR PAYBACK	E) FUTURE POTENTIAL TO PLAN RECOVERY	F))UBTFUL OR LEAST LIKELY TO BE VIABLE UNDER EXISTING CIRCUMSTANCES
GRISE FIORD			✓			
HALL BEACH				✓		
HOLMAN ISLAND				✓		
IGLOOLIK		✓	✓			
JEAN MARIE RIVER						✓
LAC LA MARTRE	✓	✓				
LAKE HARBOUR			✓			
NAHANNI BUTTE						✓
PANGNIRTUNG			✓			
PAULATUK					✓	
PELLY BAY		✓	✓			
POND INLET			✓			
E LAKES					✓	
RANKIN INLET		✓				
REPULSE BAY			✓			
SACHS HARBOUR				✓		
SNOWDRIFT				✓		
SPENCE BAY			✓			
LE LOVE				✓		
WRIGLEY					✓	

2. SCOPE OF WORK

2.1 GENERAL

The purpose of this Study is to demonstrate how much residual heat can be economically recovered from diesel generating plant without adversely affecting the operation or reliability of the diesel engines.

The objectives of the Study must be clearly understood to ensure that the methodology meets the intent. In preparing these sections of the proposal, we have made free use of verbatim quotations from the comprehensive Terms of Reference and other documentation provided to us, rearranged and amplified where appropriate to clarity in our presentation. Further changes to the given wording will be found in the cryptic task definition on our Project Schedule and Manpower Allocations. These modifications are for illustrative or semantic reasons only, and are not intended to suggest alternative purpose.

2.2 SPECIFIC DEVIATIONS

The Call for Proposals allows for variations from specific clauses of the Terms of Reference, where they could benefit the end result of the Study. In two areas, we note requirements which, if followed as implied, might result in unnecessary expenditure of Government funds. These are:

a) Task A (ii) infers that travel to GNWT Regional offices may be required to obtain all building information: since we cannot know in advance of the Study which of the listed communities may not be properly represented in GNWT or NCPC offices in Yellowknife or Edmonton, we have included no allowances for such site visits and presume the ability to negotiate travel funds if necessary.

b) Task B (i) requires "continuous readings" (which we interpret to mean serial data of sufficient frequency to reflect all trends) be taken of numerous parameters in the Lac La Martre and Cambridge Bay installations: as noted in the Introduction we are uncertain as to the extent of existing instrumentation, particularly at Cambridge Bay, but rather than commit ourselves to purchasing our prefered data acquisition equipment we have shown the additional engineering and procurement costs as a conditional extra to the Contract.

2.3 OBJECTIVES

Specific objectives of the Study (as outlined on Page 1 of the Terms of Reference) are:-

A. "Obtain and analyze information to establish the viability of recovering residual heat from the NCPC diesel-electric generating plant in each N.W.T. community, in accordance with the attached list (Appendix 'A').

B. "To assemble construction and performance data for existing heat recovery installations.

C. "To analyze methods and equipment with the intent of optimizing the heat recovery process".

2.4 METHODOLOGY

To achieve the objectives outlined under 2.3, and thereby to address the Study requirements as outlined on pages 2 to 6 of the Terms of Reference, the proposed work would consist of the following:

TASK A: - To obtain and analyze information to establish the viability (technical and economic) of recovering residual heat from the existing NCPC diesel-electric generating plant in each NWT community listed in Appendix 'A'.

a) Obtain from senior NCPC engineering and operating personnel the operating specifications, power generation records, estimated growth of power demand, any plans for expansion or modification to plant, NCPC's requirements for installation of heat recovery equipment and their views on feasibility and appropriateness of installing heat recovery equipment and limitations of each of the NCPC diesel electric generating plants listed in Appendix 'A'.
b) Collect data on each community listed in Appendix 'A' from the GNWT and NCPC and evaluate the potential uses for recovered residual heat considering location, size, construction type, use and estimated or actual heat load of all buildings relative to the generating plant or any new large buildings (such as schools, community halls) planned for each location, supplementing available data where necessary to ensure subsequent evaluations are based on actual existing conditions.
c) Use the electrical generation statistics provided by NCPC to estimate the average amount and temperature of residual heat available at each location for each month of the year.
d) Develop alternative concepts for the recovery, distribution and utilization of residual heat and evaluate each concept in terms of the amount of residual heat which can be recovered: such concepts would include:
    - Use of jacket water alone to heat buildings, fuel storage tanks, water supply/distribution systems,

recreational centres (swimming pool), small greenhouses, etc.

- Use of exhaust heat alone to heat the same as above.
- Use of jacket water heat and exhaust heat to accomplish same as above.

e) Estimate for each alternative, in conjunction with NCPC and building owners, the capital cost of renovations required to incorporate the heat recovery equipment in the plant, the distribution system required and the alterations required within the buildings to be heated.

f) Assess the cost effectiveness of each alternative on a 20-year life cycle cost in consideration of all capital, operating and maintenance costs. Group the above into 5, 10, and 15 year payback projects and priorize within these groups.

TASK B: - To assemble construction and performance data for each of the five listed existing Residual Heat Recovery installations, with particular emphasis on the differences in reliability, operability and efficiency between the Lac La Martre (jacket and exhaust recovery) and Cambridge Bay (jacket only, dual-loop multiple-user) systems.

a) Determine the data require from the Lac La Martre (exhaust and jacket recovery) and Cambridge Bay (jacket recovery) heat recovery installations to accurately calculate the performance of the installed heat recovery process, visit each site to evaluate the operating status of existing instrumentation and assess the need for additional instrumentation, coordinate with GNWT and/or NCPC for the installation and commissioning of additional instrumentation, and collect information from both installations over a period of two months in order to carry out a full assessment of the heat recovery process: information collected should include serial(under 5-minute interval) readings of at least the following data:

- electrical load for each generator in operation.
- coolant temperatures (in and out on the heat exchanger primary and secondary sides.
- outside air temperature.
- exhaust boiler fluid temperatures (in and out).
- exhaust gas temperatures (before and after boiler).
- heat distribution mains temperatures (supply and return) at the loads.
- flows in the distribution mains.
- building internal heating system temperatures (supply and return).
- building daily fuel consumption.
- any other readings available, temperature, Btu, flow or other meters on the system.

b) Assemble all data available for the heat recovery installations at NCPC plants in Pelly Bay, Rankin Inlet, Fort Simpson (if available), and Igloolik.

c) Determine the proportion of waste heat available for recovery from the existing installations that has not been utilized, and provide this information on a yearly basis summarized by month.

d) Assemble a historical record of existing installations (including operating and maintenance costs, equipment failures and replacements and downtime), an overall assessment of the performance of the system (in terms of cost savings, utilization of available residual heat and any other direct or indirect benefits that may have materialized), and an objective comparison between the results achieved in these systems against data published on other heat recovery installations both in the NWT and elsewhere.

e) Assess the remaining useful life of each existing system, and the potential for extending the life and reducing operating and maintenance costs.

Depending on the extent and complexity of instrumentation now in place in each site, consideration will be given to portable electronic data acquisition equipment (such as the Hewlett-Packard HP41CV/3421A, with input from non-invasive temperature sensors and appropriate flow transducers) as a convenient and highly accurate alternative to manual data collection/interpretation. Costs of such equipment would be within budgeted range, and would in any event be offset by reduction in manual monitoring.

TASK C: - To analyze existing and potential Residual Heat Recovery methods, and equipment, to optimize the heat recovery process and to maximize the economic benefits of both existing and any new installations.

a) Utilize the data gathered through Tasks 'A' and 'B' and other sources (such as climatic information, population trends, developments in building design) to analyze and report on the following factors as they relate to the plants listed in Appendix 'A':
   - correlation between electrical load and daily and seasonal climatic factors.
   - effect of changes in heating load (flow and/or temperatures) on heat exchange efficiency.
   - methods (such as prediction of load change and provision of thermal inertia) to achieve optimum balance between electrical load and heating load.
   - optimum operating temperature ranges of heating fluid from a standpoint of diesel generator protection and efficiency.
   - optimum operating temperature ranges of heating fluid from a standpoint of recovery equipment selection and pipe sizing.
   - optimum combination of heat exchangers at the plant in relation to heat required in the

buildings supplied with heat, with regard to operating cycles.
- costs of distributing recovered heat to a single large user, compared to several small users.
- impact of using residual heat on building construction, operating and maintenance costs.
- costs of retrofitting existing buildings to utilize the recovered heat versus providing the heat to new buildings.

b) evaluate alternative concepts to optimize utilization of residual heat. Alternatives should strive to utilize all available residual heat and use any existing heating equipment to supplement heating requirements beyond that available from the residual heating system.

Due to the remote location of these installations, it is imperative that the equipment selected for use with any heat recovery scheme be durable and require minimal maintenance. We visualize the jacket water and exhaust gas heat exchangers to be critical to the operation of any efficient residual heat recovery scheme. It is important therefore that the study team have the ability to review standard "off-the-shelf" heat exchangers, as well as the technical capability to design custom heat exchangers from first principles to provide an appropriate bench-mark for evaluation. Of particular interest is the gas-to-liquid heat exchanger used to recover heat from the exhaust gas stream, which requires careful consideration, not only of temperature extremes but also of the possibly damaging effects of excessive back pressure on the engine.

APPENDIX "B"

DETAILED SHEETS OF DIESEL GENERATOR DATA FOR VARIOUS SITES

Site: Aklavik

	No. of Generators		
	1	2	3
Rating - Prime (kW)	600	300	600
Model	D398	D353	D398
Aspiration	TC/AC	TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	241	140	241
- Max Hd. on Pump - Outlet ft	30	30	30
- Inlet ft	58	58	58
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)	1,890,000	936,000	1,890,000
- Pipe Dia. (inches) - In			
- Out	4.5	3	4.5
- Comb. Air - (CFM)	2100	1000	2100
- °C	29	29	29
- Exhaust - (CFM)	5000	2440	5000
- °C	441	470	441
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	10 or 12	8	10 or 12
- Max. P Allowed Inches WG	27	27	27
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooler

Site: Arctic Bay

	No. of Generators		
	1	2	3
Rating - Prime (kW)	250	400	400
Model	D343	D379	D379
Aspiration			
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	133-158	290-346	290-346
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out	3	4.5	4.5
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)	2200	3260	3260
- °C	432	518	518
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	6	10	10
- Max. P Allowed Inches WG	27	27	27
Radiated Heat (BTU/hr)			

Site: Arctic Red River

	No. of Generators			
	1	2	3	4
Rating - Prime (kW)	50	80	150	80
Model	H6-1P	4-71	NH220	4-71
Aspiration				
Manufacturer	Cummins	G.M.	Cummins	Detroit Diesel
Cooling Water				
- Flow @ Max. Hd. (igpm)				
- Max Hd. on Pump - Outlet ft				
- Inlet ft				
- Temp. °C - In				
- Out				
- Heat Rejected (BTU/hr)				
- Pipe Dia. (inches) - In				
- Out				
- Comb. Air - (CFM)				
- °C				
- Exhaust - (CFM)				
- °C				
- Heat Rejected (BTU/hr)				
- Stack Dia. (inches)				
- Max. P Allowed Inches WG				3.3 hg = 45" in H_2O
Radiated Heat (BTU/hr)				

Site: Baker Lake

	No. of Generators			
	1	2	3	4
Rating - Prime (kW)	200	704	550	720
Model	TL6	EWSL8	D398	D399
Aspiration				
Manufacturer	Mirrlees	Blackstone	Caterpillar	Caterpillar
Cooling Water				
- Flow @ Max. Hd. (igpm)			241-288	325-348
- Max Hd. on Pump - Outlet ft				
- Inlet ft				
- Temp. °C - In			85	85
- Out			93	93
- Heat Rejected (BTU/hr)				
- Pipe Dia. (inches) - In				
- Out			4.5	4.5
- Comb. Air - (CFM)				
- °C				
- Exhaust - (CFM)			4830	6390
- °C			443	477
- Heat Rejected (BTU/hr)				
- Stack Dia. (inches)			10-12	12
- Max. P Allowed Inches WG				
Radiated Heat (BTU/hr)				

Site: Broughton Island

	No. of Generators		
	1	2	3
Rating - Prime (kW)	165	165	300
Model	D342	D342	D353
Aspiration			TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	85-104	85-104	140
- Max Hd. on Pump - Outlet ft			30
- Inlet ft			58
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)			936,000
- Pipe Dia. (inches) - In			
- Out	2.5	2.5	3
- Comb. Air - (CFM)			1000
- °C			29
- Exhaust - (CFM)	875	875	2440
- °C	399	399	470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	6	6	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Cambridge Bay

No. of Generators

	1	2	3[+]	4[+]	5[+]
Rating - Prime (kW)	800	800	350	375	575
Type	D-399	D-399	EVS-8	EVS-8	ESS-8
Aspiration	TC/AC	TC/AC	-	-	-
Manufacturer	Caterpillar	Caterpillar	Lister-Blackstone	Lister-Blackstone	Lister-Blackstone
Cooling Water	-	-	-	-	-
- Flow @ Max. Hd. (igpm)	326-340	326-340	-	-	-
- Max Hd. on Pump - Outlet	30*	30*	-	-	-
- Inlet	-	-	-	-	-
- Temp. °C - In	70	70	-	-	76
- Out	90-99	90-99	-	-	-
- Heat Rejected (BTU/hr)	2.52×10^6	2.52×10^6	-	-	2500 BTU/HP
- Pipe Dia. (inches) - In	4.5	4.5	-	-	-
- Out	4.5	4.5	2	2	-
- Comb. Air - (CFM)	2500	2500	-	-	-
- °C	29	29	-	-	-
- Exhaust - (CFM)	6390	6390	-	-	-
- °C	477	477	-	-	382
- Heat Rejected (BTU/hr)	-	-	-	-	-
- Stack Dia. (inches)	12	12	9	9	-
- Max. P Allowed	27	27	-	-	5
Radiated Heat (BTU/hr)	0.6×10^6	0.6×10^6	-	-	-

Remarks: * MAX. TOTAL DYNAMIC HEAD (TDH) ON PUMP IS 57 FT. FLOW AT THIS TDH NOT KNOWN.

[+] MANUFACTURER DID NOT PROVIDE REQUIRED INFORMATION.

TC/AC = TURBOCHARGED/AFTERCOOLER

Site: Cape Dorset

	No. of Generators				
	1	2	3	4	5
Rating - Prime (kW)	720	720	375	375	
Model	D399	D399	EVS8	EVS8	ESS8
Aspiration	TC	TC			
Manufacturer	Caterpillar	Caterpillar	Blackstone**	Blackstone**	Blackstone**
Cooling Water					
- Flow @ Max. Hd. (igpm)	326-348	326-348	50	50	-
- Max Hd. on Pump - Outlet ft	30 ft*	30*			
- Inlet ft	-	-			
- Temp. °C - In	70	70	76	76	76
- Out	90-99	90-99			
- Heat Rejected (BTU/hr)	2.52×10^6	2.52×10^6	2500 BTU/hp	2500 BTU/hp	2500 BTU/hp
- Pipe Dia. (inches) - In	4.5	4.5	2	2	-
- Out	4.5	4.5	2	2	-
- Comb. Air - (CFM)	2500	2500	-	-	-
- °C	29	29	-	-	-
- Exhaust - (CFM)	6390	6390	-	-	-
- °C	477	477	382	382	382
- Heat Rejected (BTU/hr)	-	-	-	-	-
- Stack Dia. (inches)	12	12	9	9	
- Max. P Allowed Inches WG	27	27	5	5	5
Radiated Heat (BTU/hr)	0.6×10^6	0.6×10^6	-	-	-

* Max. Total Dynamic Head (TDH) on pump is 57 ft.. Flow at this TDH is unknown.

** Minimal info available from manufacturer.

TC/AC = Turbocharged/aftercooled

Site: Chesterfield Inlet

	No. of Generators		
	1	2	3
Rating - Prime (kW)	150	200	300
Model	D336YA	D334TA	D353TA
Aspiration	TC/AC	TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)		79-90	133-159
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In		85	85
- Out		93	93
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In		2.5	3
- Out			
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)		1740	2380
- °C		538	468
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)		6	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Clyde River

	No. of Generators		
	1	2	3
Rating - Prime (kW)	300	300	500
Model	D353	D353E	D398
Aspiration			
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	133-159		241-288
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In	85		85
- Out	93		93
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out	3		4.5
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)	2380		4830
- °C	468		443
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	8		10-12
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Site: Coppermine

	No. of Generators				
	1	2	3	4	5
Rating - Prime (kW)	200	200	300	375	600
Model	EV6	EV6	EV6	EVS8	D398
Aspiration					TC/AC
Manufacturer	Blackstone	Blackstone	Blackstone	Blackstone	Caterpillar
Cooling Water					
- Flow @ Max. Hd. (igpm)					241
- Max Hd. on Pump - Outlet ft					30
- Inlet ft					58
- Temp. °C - In					85
- Out					93
- Heat Rejected (BTU/hr)					1,890,000
- Pipe Dia. (inches) - In					
- Out	2	2	2	2	4.5
- Comb. Air - (CFM)					2100
- °C					29
- Exhaust - (CFM)					5000
- °C					441
- Heat Rejected (BTU/hr)					
- Stack Dia. (inches)	5	5	5	9	10-12
- Max. P Allowed Inches WG					27"
Radiated Heat (BTU/hr)					

TC/AC = Turbocharged/aftercooled

Site: Coral Harbour (2/2)
Airport Plant
(formerly MOT plant)

	No. of Generators		
	1	2	3
Rating - Prime (kW)	250	250	250
Model	D397	D397	D397
Aspiration			
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)			
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In			
- Out			
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out			
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)			
- °C			
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)			
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Site Coral Harbour (1/2)

	No. of Generators	
	1	2
Rating - Prime (kW)	300	300
Model	D353TA	D353
Aspiration	TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar
Cooling Water		
- Flow @ Max. Hd. (igpm)	140	140
- Max Hd. on Pump - Outlet ft	30	30
- Inlet ft	58	58
- Temp. °C - In	85	85
- Out	93	93
- Heat Rejected (BTU/hr)	936,000	936,000
- Pipe Dia. (inches) - In		
- Out	3	3
- Comb. Air - (CFM)	1000	1000
- °C	29	29
- Exhaust - (CFM)	2440	2400
- °C	470	470
- Heat Rejected (BTU/hr)		
- Stack Dia. (inches)	8	8
- Max. P Allowed Inches WG		
Radiated Heat (BTU/hr)		

TC/AC = Turbocharged/aftercooled

Site: Eskimo Point

	No. of Generators			
	1	2	3	4
Rating - Prime (kW)	300	300	600	600
Model	D353	D353	D398	D398
Aspiration	TC/AC	TC/AC	TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar	Caterpillar
Cooling Water				
- Flow @ Max. Hd. (igpm)	140	140	241	241
- Max Hd. on Pump - Outlet ft	30	30	30	30
- Inlet ft	58	58	58	58
- Temp. °C - In	85	85	85	85
- Out	93	93	93	93
- Heat Rejected (BTU/hr)	936,000	936,000	1,890,000	1,890,000
- Pipe Dia. (inches) - In				
- Out	3	3	4.5	4.5
- Comb. Air - (CFM)	1000	1000	2100	2100
- °C	29	29	29	29
- Exhaust - (CFM)	2400	2400	5000	5000
- °C	470	470	441	441
- Heat Rejected (BTU/hr)				
- Stack Dia. (inches)	8	8	10-12	10-12
- Max. P Allowed Inches WG				
Radiated Heat (BTU/hr)				

TC/AC = Turbocharged/aftercooled

Site: Fort Franklin

	No. of Generators		
	1	2	3
Rating - Prime (kW)	300	200	300
Model	D353	NTA400G	D353
Aspiration	TC/AC		TC/AC
Manufacturer	Caterpillar	Cummins	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	140		140
- Max Hd. on Pump - Outlet ft	30		30
- Inlet ft	58		58
- Temp. °C - In	85		85
- Out	93		93
- Heat Rejected (BTU/hr)	936,000		936,000
- Pipe Dia. (inches) - In			
- Out	3		3
- Comb. Air - (CFM)	1000		1000
- °C	29		29
- Exhaust - (CFM)	2440		2440
- °C	470		470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	8		8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC - Turbocharged/Aftercooled

Existing heat recovery system for internal use @ plant only; jacket and exhaust - see report below

Report: "Fort Franklin Waste Heat Recovery Feasibility Study" indicates that unit #2 was to be replaced by Fall 84 w/a 600 KW unit

Site: Fort Good Hope

	No. of Generators		
	1	2	3
Rating - Prime (kW)	300	300	300
Model	D353E	D353E	D353E
Aspiration			
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)			
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out	3	3	3
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)	2380	2380	2380
- °C	468	468	468
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	8	8	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Site: Fort Liard

	No. of Generators		
	1	2	3
Rating - Prime (kW)	150	200	185
Model	NH220	Nt335G6	3406
Aspiration			Turbocharged
Manufacturer	Cummins	Cummins	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)			84
- Max Hd. on Pump - Outlet ft			30
- Inlet ft			57.7
- Temp. °C - In			85
- Out			93
- Heat Rejected (BTU/hr)			432,000
- Pipe Dia. (inches) - In			
- Out			2.5
- Comb. Air - (CFM)			610
- °C			29
- Exhaust - (CFM)			1635
- °C			527
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)			6
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Site: Fort McPherson

	No. of Generators		
	1	2	3
Rating - Prime (kW)	375	375	600
Model	EV58	EV58	D398
Aspiration			TC/AC
Manufacturer	Blackstone	Blackstone	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)			241
- Max Hd. on Pump - Outlet ft			30
- Inlet ft			58
- Temp. °C - In			85
- Out			93
- Heat Rejected (BTU/hr)			1,890,000
- Pipe Dia. (inches) - In			
- Out			4.5
- Comb. Air - (CFM)			2100
- °C			29
- Exhaust - (CFM)			5000
- °C			441
- Heat Rejected (BTU/hr			
- Stack Dia. (inches)	10	10	10-12
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Fort Norman

	No. of Generators		
	1	2	3
Rating - Prime (kW)	300	200	400
Model	KT1150	12V71	D379
Aspiration	Turbocharged		
Manufacturer	Cummins	Detroit Diesel	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	171		241-288
- Max Hd. on Pump - Outlet ft	35		
- Inlet ft	30		
- Temp. °C - In			85
- Out	85		93
- Heat Rejected (BTU/hr)	655200		
- Pipe Dia. (inches) - In			
- Out			4.5
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)	2300		3260
- °C	474		518
- Heat Rejected (BTU/hr)	792,000		
- Stack Dia. (inches)			10
- Max. P Allowed Inches WG	41		
Radiated Heat (BTU/hr)	216,000		

Site: Fort Simpson

			No. of Generators		
	1	2	3	4	5
Rating - Prime (kW)	1000	1800	2085	600	50
Model	8CSV	12RKC	251B16	6ATX	DD4-71
Aspiration					
Manufacturer	Rushton-Hornsby	Rushton	MLW 16 CYL	Rushton-Hornsby	Delco
Cooling Water					
- Flow @ Max. Hd. (igpm)					
- Max Hd. on Pump - Outlet ft					
- Inlet ft					
- Temp. °C - In					
- Out					
- Heat Rejected (BTU/hr)					
- Pipe Dia. (inches) - In					
- Out					
- Comb. Air - (CFM)					
- °C					
- Exhaust - (CFM)					
- °C					
- Heat Rejected (BTU/hr)					
- Stack Dia. (inches)					
- Max. P Allowed Inches WG					
Radiated Heat (BTU/hr)					

Site: Gjoa Haven

	No. of Generators		
	1	2	3
Rating - Prime (kW)	300	150	300
Model	D353	D342	D353
Aspiration	TC/AC		TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	140	85-104	140
- Max Hd. on Pump - Outlet ft	30		30
- Inlet ft	58		58
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)	936,000		936,000
- Pipe Dia. (inches) - In			
- Out	3	2.5	3
- Comb. Air - (CFM)	1000		1000
- °C	29		29
- Exhaust - (CFM)	2440	875	2440
- °C	470	399	470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	8	6	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Grise Fiord

	No. of Generators		
	1	2	3
Rating - Prime (kW)	200	140	80
Model	Nt335	3306	DD4-71
Aspiration			
Manufacturer	Cummins	Caterpillar	GM
Cooling Water			
- Flow @ Max. Hd. (igpm)			
- Max Hd. on Pump - Outlet ft		38	
- Inlet ft			
- Temp. °C - In		85	
- Out		93	
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out		2.5	
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)		1010	
- °C		482	
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	5	6	
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Report prepared for EMR Canada: "Heat Recovery Potential from Diesel Electric Generating Plants in Pond Inlet and Grise Fiord, NWT"

Site: Hall Beach

	No. of Generators		
	1	2	3
Rating - Prime (kW)	185	300	300
Model	3406	D353	D353
Aspiration	Turbocharged	TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	84	140	140
- Max Hd. on Pump - Outlet ft	30	30	30
- Inlet ft	57.7	58	58
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)	432,000	936,000	936,000
- Pipe Dia. (inches) - In			
- Out	2.5	3	3
- Comb. Air - (CFM)	610	1000	1000
- °C	29	29	29
- Exhaust - (CFM)	1635	2440	2440
- °C	527	470	470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	6	8	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Holman Island

	No. of Generators	
	1	2
Rating - Prime (kW)	150	300
Model	D342	KTA11506
Aspiration		TC/AC
Manufacturer	Caterpiller	Cummins
Cooling Water		
- Flow @ Max. Hd. (igpm)	85-104	157
- Max Hd. on Pump - Outlet ft		35
- Inlet ft		30
- Temp. °C - In	85	
- Out	93	85
- Heat Rejected (BTU/hr)		999900
- Pipe Dia. (inches) - In		
- Out	2.5	
- Comb. Air - (CFM)		
- °C		
- Exhaust - (CFM)	875	3020
- °C	399	504
- Heat Rejected (BTU/hr)		958200
- Stack Dia. (inches)	6	5
- Max. P Allowed Inches WG		
Radiated Heat (BTU/hr)		258000

TC/AC = Turbocharged/aftercooled

Site: Igloolik

	No. of Generators		
	1	2	3
Rating - Prime (kW)	600	300	300
Model	D398	D353	D353
Aspiration	TC/AC	TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	241	140	140
- Max Hd. on Pump - Outlet ft	30	30	30
- Inlet ft	58	58	58
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)	1,890,000	936,000	936,000
- Pipe Dia. (inches) - In			
- Out	4.5	3	3
- Comb. Air - (CFM)	2100	1000	1000
- °C	29	29	29
- Exhaust - (CFM)	5000	2440	2400
- °C	441	470	470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	10-12	8	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Jean Marie River

	No. of Generators		
	1	2	3
Rating - Prime (kW)	40	21	80
Model	DD4-71	DD253	DD4-71
Aspiration			
Manufacturer	GM	GM	GM
Cooling Water			
- Flow @ Max. Hd. (igpm)			
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In			
- Out			
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out			
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)			
- °C			
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)			
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Site: Lake Harbour

	No. of Generators		
	1	2	3
Rating - Prime (kW)	150	300	300
Model	D342	D353	D353
Aspiration		TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	85-104	140	140
- Max Hd. on Pump - Outlet ft		30	30
- Inlet ft		58	58
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)		936,000	936,000
- Pipe Dia. (inches) - In			
- Out	2.5	3	3
- Comb. Air - (CFM)		1000	1000
- °C		29	29
- Exhaust - (CFM)	875	2440	2440
- °C	399	470	470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	6	8	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Lac La Martre

	No. of Generators		
	1*	2	3
Rating - Prime (kW)	225 kW	80 kW	150 kW
Model	3408	DD471	D342
Aspiration			
Manufacturer	Caterpillar	GM	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)			
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In			
- Out			
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out			
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)			
- °C			
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)			
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

* Ferguson Simek Report states this unit as Cat.3406 with a kVA rating of 281 at a 0.8 P.F. The 3406 produces only 250kVA @ 0.8 P.F. to produce 281 kVA @ 0.8 P.F. (1800 RPM) must go to a Cat.3408.

Site: Nahanni Butte

		No. of Generators	
	1	2	3
Rating - Prime (kW)	21	50	80
Model	DD253	DD4-71	DD4-71
Aspiration			
Manufacturer	GM	GM	GM
Cooling Water			
- Flow @ Max. Hd. (igpm)			
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In			
- Out			
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out			
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)			
- °C			
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)			
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Site: Pangnirtung

	No. of Generators			
	1	2	3	4
Rating - Prime (kW)	300	300	600	600
Model	D353TA	D353	D398	D398
Aspiration	TC/AC	TC/AC	TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar	Caterpillar
Cooling Water				
- Flow @ Max. Hd. (igpm)	140	140	241	241
- Max Hd. on Pump - Outlet ft	30	30	30	30
- Inlet ft	58	58	58	58
- Temp. °C - In	85	85	85	85
- Out	93	93	93	93
- Heat Rejected (BTU/hr)	936,000	936,000	1,890,000	1,890,000
- Pipe Dia. (inches) - In				
- Out	3	3	4.5	4.5
- Comb. Air - (CFM)	1000	1000	2100	2100
- °C	29	29	29	29
- Exhaust - (CFM)	2440	2440	5000	5000
- °C	470	470	441	441
- Heat Rejected (BTU/hr)				
- Stack Dia. (inches)	8	8	10-12	10-12
- Max. P Allowed Inches WG				
Radiated Heat (BTU/hr)				

TC/AC = Turbocharged/aftercooled

Site: Paulatuk

	No. of Generators			
	1	2	3	4
Rating - Prime (kW)	80	100	150	150
Model	DD471	DD6V-71	D-334	D-342
Aspiration				
Manufacturer	GM	GM	Caterpillar	Caterpillar
Cooling Water				
- Flow @ Max. Hd. (igpm)			79-90	
- Max Hd. on Pump - Outlet ft				
- Inlet ft				
- Temp. °C - In			85	85
- Out			93	93
- Heat Rejected (BTU/hr)				
- Pipe Dia. (inches) - In			2.5	2.5
- Out				
- Comb. Air - (CFM)			1740	875
- °C			538	399
- °C			6	6
- Heat Rejected (BTU/hr)				
- Stack Dia. (inches)				
- Max. P Allowed Inches WG				
Radiated Heat (BTU/hr)				

Site: Pelly Bay

	No. of Generators		
	1	2	3
Rating - Prime (kW)	200	300	300
Model	8V71	D353	D353
Aspiration		TC/AC	TC/AC
Manufacturer	Detroit Diesel	Caterpillar	Caterpillar
- Flow @ Max. Hd. (igpm)		140	140
- Max Hd. on Pump - Outlet ft		30	30
- Inlet ft		58	58
- Temp. °C - In		85	85
- Out		93	93
- Heat Rejected (BTU/hr)		936,000	936,000
- Pipe Dia. (inches) - In			
- Out		3	3
- Comb. Air - (CFM)		1000	1000
- °C		29	29
- Exhaust - (CFM)		2440	2440
- °C		470	470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)		8	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC - Turbocharged/aftercooled

Site: Pond Inlet

	No. of Generators		
	1	2	3
Rating - Prime (kW)	300	600	720
Model	D353	D398	D399
Aspiration	TC/AC	TC/AC	
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	140	241	325-348
- Max Hd. on Pump - Outlet ft	30	30	
- Inlet ft	58	58	
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)	936,000	1,890,000	
- Pipe Dia. (inches) - In			
- Out	3	4.5	4.5
- Comb. Air - (CFM)	1000	2100	
- °C	29	29	
- Exhaust - (CFM)	2440	5000	6390
- °C	470	441	477
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	8	10-12	12
- Max. P Allowed Inches WG			

TC/AC = Turbocharged/aftercooled

Report prepared for EMR Canada "Heat Recovery Potential from Diesel Electric Generating Plants in Pond Inlet and Grise Fiord, NWT"

Site Rae Lakes

	No. of Generators	
	1	2
Rating - Prime (kW)	100	80
Model	D3306	DD471
Aspiration		
Manufacturer	Caterpillar	GM
Cooling Water		
- Flow @ Max. Hd. (igpm)	38	
- Max Hd. on Pump - Outlet ft		
- Inlet ft		
- Temp. °C - In	85	
- Out	93	
- Heat Rejected (BTU/hr)		
- Pipe Dia. (inches) - In		
- Out	2.5	
- Comb. Air - (CFM)		
- °C		
- Exhaust - (CFM)	1010	
- °C	482	
- Heat Rejected (BTU/hr)		
- Stack Dia. (inches)	6	
- Max. P Allowed Inches WG		
Radiated Heat (BTU/hr)		

Site: Rankin Inlet

	No. of Generators			
	1	2	3	4
Rating - Prime (kW)	700	700	720	600
Model	D399	D399	D399	D398
Aspiration				TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar	Caterpillar
Cooling Water				
- Flow @ Max. Hd. (igpm)	325-348	325-348	325-348	241
- Max Hd. on Pump - Outlet ft				30
- Inlet ft				58
- Temp. °C - In	85	85	85	85
- Out	93	93	93	93
- Heat Rejected (BTU/hr)				1,890,000
- Pipe Dia. (inches) - In				
- Out	4.5	4.5	4.5	4.5
- Comb. Air - (CFM)				2100
- °C				29
- Exhaust - (CFM)	6390	6390	6390	5000
- °C	477	477	477	441
- Heat Rejected (BTU/hr)				
- Stack Dia. (inches)	12	12	12	10-12
- Max. P Allowed Inches WG				
Radiated Heat (BTU/hr)				

TC/AC = Turbocharged/aftercooled

Site: Repulse Bay

		No. of Generators	
	1	2	3
Rating - Prime (kW)	150	300	300
Model	D342TA	D353	D353
Aspiration		TC/AC	TC/AC
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	85-104	140	140
- Max Hd. on Pump - Outlet ft		30	30
- Inlet ft		58	58
- Temp. °C - In	85	85	85
- Out	93	93	93
- Heat Rejected (BTU/hr)		936,000	936,000
- Pipe Dia. (inches) - In			
- Out	2.5	3	3
- Comb. Air - (CFM)		1000	1000
- °C		29	29
- Exhaust - (CFM)	875	2440	2440
- °C	399	470	470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	6	8	8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Sachs Harbour

	No. of Generators		
	1	2	3
Rating - Prime (kW)	300	300	100
Model	D353	D353	D353
Aspiration	TC/AC	TC/AC	
Manufacturer	Caterpillar	Caterpillar	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	140	140	
- Max Hd. on Pump - Outlet ft	30	30	
- Inlet ft	58	58	
- Temp. °C - In	85	85	
- Out	93	93	
- Heat Rejected (BTU/hr)	936,000	936,000	
- Pipe Dia. (inches) - In			
- Out	3	3	
- Comb. Air - (CFM)	1000	1000	
- °C	29	29	
- Exhaust - (CFM)	2440	2440	
- °C	470	470	
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	8	8	
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

TC/AC = Turbocharged/aftercooled

Site: Snowdrift

	No. of Generators		
	1	2	3
Rating - Prime (kW)	150	200	80
Model	D342	DD8V71	DD4-71
Aspiration			
Manufacturer	Caterpillar	GM	GM
Cooling Water			
- Flow @ Max. Hd. (igpm)	85-104		
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In	85		
- Out	93		
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out	2.5		
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)	875		
- °C	399		
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	6		
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

Site: Spence Bay

	No. of Generators			
	1	2	3	4
Rating - Prime (kW)	150	150	300	300
Model	D342	D342	D353	D353
Aspiration			TC/AC	TC/C
Manufacturer	Caterpillar	Caterpillar	Caterpillar	Caterpillar
Cooling Water				
- Flow @ Max. Hd. (igpm)	85-104	85-104	140	140
- Max Hd. on Pump - Outlet ft			30	30
- Inlet ft			58	58
- Temp. °C - In	85	85	85	85
- Out	93	93	93	93
- Heat Rejected (BTU/hr)			936,000	936,000
- Pipe Dia. (inches) - In				
- Out	2.5	2.5	3	3
- Comb. Air - (CFM)			1000	1000
- °C			29	29
- Exhaust - (CFM)	875	875	2440	2440
- °C	399	399	470	470
- Heat Rejected (BTU/hr)				
- Stack Dia. (inches)	6	6	8	8
- Max. P Allowed Inches WG				
Radiated Heat (BTU/hr)				

TC/AC = Turbocharged/aftercooled

Site: Whale Cove

	No. of Generators		
	1	2	3
Rating - Prime (kW)	150	200	300
Model	D342TA	NT335GS	D353
Aspiration	TC/AC		TC/AC
Manufacturer	Caterpillar	Cummins	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)	85-104		140
- Max Hd. on Pump - Outlet ft			30
- Inlet ft			58
- Temp. °C - In	85		85
- Out	93		93
- Heat Rejected (BTU/hr)			936,000
- Pipe Dia. (inches) - In			
- Out	2.5		3
- Comb. Air - (CFM)			1000
- °C			29
- Exhaust - (CFM)	875		2440
- °C	399		470
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)	6		8
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

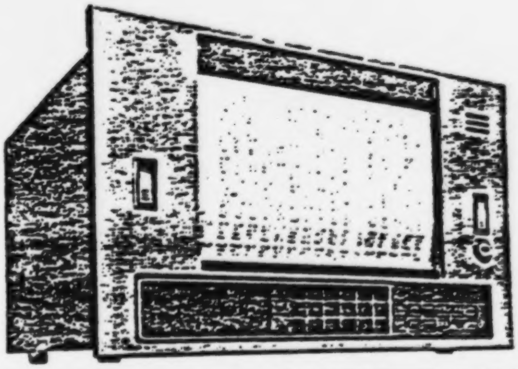
TC/AC = Turbocharged/aftercooled

Site: Wrigley

	No. of Generators		
	1	2	3
Rating - Prime (kW)	150	200	130
Model	6-71	8V-71	D3306
Aspiration			
Manufacturer	Detroit Diesel	General Motors	Caterpillar
Cooling Water			
- Flow @ Max. Hd. (igpm)			
- Max Hd. on Pump - Outlet ft			
- Inlet ft			
- Temp. °C - In			85
- Out			93
- Heat Rejected (BTU/hr)			
- Pipe Dia. (inches) - In			
- Out			2.5
- Comb. Air - (CFM)			
- °C			
- Exhaust - (CFM)			1010
- °C			481
- Heat Rejected (BTU/hr)			
- Stack Dia. (inches)			6
- Max. P Allowed Inches WG			
Radiated Heat (BTU/hr)			

APPENDIX "C-1"

MONITORING EQUIPMENT



DIGISTRIP III

Dimensions
Standard: 49.3 cm wide x 31.1 cm high x 51.4 cm deep
(19.0 in. wide x 12.2 in. high x 20.2 in. deep)
High Accuracy: 49.3 cm wide x 31.1 cm high x 57.7 cm deep
(19.0 in. wide x 12.2 in. high x 22.7 in. deep)

Weight
Standard: 28.2 Kg
(62 lbs)
High Accuracy: 31.8 Kg
(70 lbs)

Power: 90-135 VAC, 50/60 Hz, or 200-270 VAC, 50/60 Hz
60 watts idling, 130 watts printing

Fuse: 1.5A Slo-Blo, 110 VAC
0.75A Slo-Blo, 220 VAC

Ambient Temperature: 0-50C (32-125F)
0-95% (non-condensing) relative humidity

Input Channel Capacity: 16 in basic configuration, expandable to 48 by 16 channel groups. Expandable to 128 channels with remote scanner

Scanning Speed: 8 channels/second basic unit, higher effective rate with remote scanner

Input Impedance: $>10^9\Omega$ after filter has settled. Source impedance should be less than 2KΩ for proper filter settling

Common Mode Rejection: 140db at DC
(1KΩ source imbalance) 130db; line frequency
120db; line freq. to 100 KHz

Maximum Common
Mode Voltage: 350 Volts peak AC or DC from channel to frame ground and from channel to channel

Normal Mode Rejection: 60db at 50 or 60 Hz

Accuracy of
Voltage Inputs: ± (0.003% reading + 1 count + 2µV) 30 days
± (0.006% reading + 1 count + 2µV) 1 year

Resolution: 1:65, 535

Sensitivity: 0.5µv (on most sensitive range)

Voltage Temperature Coefficient: ± (0.1µV + 0.001% reading) C

Compensator Temperature Coefficient: ±0.02C/C

Temperature Non-Uniformity of Input Terminals
Standard: ±0.3C
High Accuracy: ±0.05C

Standard Functions:
Voltage: 65 mv, 650 mv, 6.5V
Thermocouples: E,J,K,R,S,T; C or F; Internal Universal Reference
Platinum RTD: 100Ω in 1 ma current loop. 100Ω in bridge configuration
User Definable Functions: 32 Linear Functions
16 Accumulation Functions

Math Functions: Interval average, interval maximum, interval minimum, change per minute, group average, group maximum, group minimum, transfer, square root, natural log, exponential, sine, cosine, tangent, inverse sine, inverse cosine, inverse tangent, addition, subtraction, multiplication, division, fourth order polynomial, compressible gas flow, relative humidity, equivalent sterilizer (F_0). (Special Order Option – Delete 0.01°C Type T and F_0, add Nicrosil/Nisil thermocouple conversion, add cylindrical and elliptical tank volume.)

Channel Skip: Individually Programmable

Assignable Limits: Two per channel, independently assignable

Limit Types: High, Low, Rate-of-Change

Relay Closures: Two, assignable by odd or even relay address. Option, up to 48 additional

Contact Configuration: Form 1C normally energized or de-energized

Contact Capacity: 4A, 250 VAC Resistive Load

Log Interval: 1 minute to 19.999 minutes. (10 seconds if set to zero)

Printer Type: 5 x 7 dot matrix, bidirectional printing on 137 column pressure sensitive fanfold paper, internal paper takeup tray

Header Data: 8 characters/channel alphanumeric header field. 128 character alphanumeric general data field

Alarm Message Output: 32 programmable alarm messages

Printer Recorder Capacity: 96,000 channel/150 page fanfold pack

Computer Interface: Via standard RS232C and 20 ma (passive) TTY ports

Input Types	Range	Conformity to NBS	Accuracy-Standard	Accuracy-High Accuracy
Voltage	32mv*, 65mv 650mv, 6500mv (6.5V)		± (0.003% reading + 1 count + 2µV)	± (0.003% reading + 1 count + 2µV)
Thermocouple, Type E	−109C to 858C (−164F to 1576F)	0.06C	± (0.003% reading + 0.5C)	± (0.003% reading + 0.25C)
Thermocouple, Type J	−112C to 1130C (−170F to 2066F)	0.06C	± (0.003% reading + 0.5C)	± (0.003% reading + 0.25C)
Thermocouple, Type K	−137C to 1392C (−215F to 2537F)	0.06C	± (0.003% reading + 0.5C)	± (0.003% reading + 0.25C)
Thermocouple, Type R	−21C to 1779C (−5F to 3234F)	0.1C above 260C 20.0C below 260C	± (0.003% reading + 0.9C)**	± (0.003% reading + 0.65C)**
Thermocouple, Type S	−21C to 1767C (−5F to 3212F)	0.1C above 260C 20.0C below 260C	± (0.003% reading + 0.9C)**	± (0.003% reading + 0.65C)**
Thermocouple, Type T	−220C to 402C (−364F to 755F)	0.06C	± (0.003% reading + 0.5C)	± (0.003% reading + 0.25C)
Thermocouple, Type T	−112C to 341C	0.02C	± (0.003% reading + 0.45C)	± (0.003% reading + 0.20C)
RTD, 100Ω Pt. 1 ma	−128C to 855C (−198F to 1571F)	0.06C***	± (0.003% reading + 0.1C)	± (0.003% reading + 0.1C)
RTD, 100Ω Pt. bridge	−125C to 808C (−193F to 1487F)	0.06C***	± (0.003% reading + 0.1C)	± (0.003% reading + 0.1C)

*32mv range used for Thermocouple Types. R, S and T measurements only
**Accuracy specification for temperatures above 260C
***Conformity to D9443760

System accuracy includes all instrument errors including maximum conformity deviations, reference junction compensation with worst case thermal scatter of input terminals, long term drift, temperature coefficients, A/D conversion errors, and scanner errors. System accuracy 30 days 20C to 30C ambient.

The AUTO CAL feature permits users to substantially improve the above listed accuracy figures by eliminating both sensor variation and system based thermal scatter effects.

DIGISTRIP III...MORE

Standardization, the key to Digistrip II and now Digistrip III, means you have an even more powerful range of standard features with which to work. It means that many applications no longer require a custom minicomputer system. Digistrip III handles the job with a package that belongs on the production floor. Digistrip III handles the job at a cost that is a fraction of the custom computer alternative.

DIGISTRIP III... MORE CHANNEL CAPACITY

Digistrip II has a maximum input capacity of 48 channels. Digistrip III has a maximum capacity of 128 channels. This additional capacity is provided by a remote multiplexer, DR-64 or DR-128 which may be located up to 1.5 kilometers away. Digistrip III is limited to 48 channels in the mainframe.

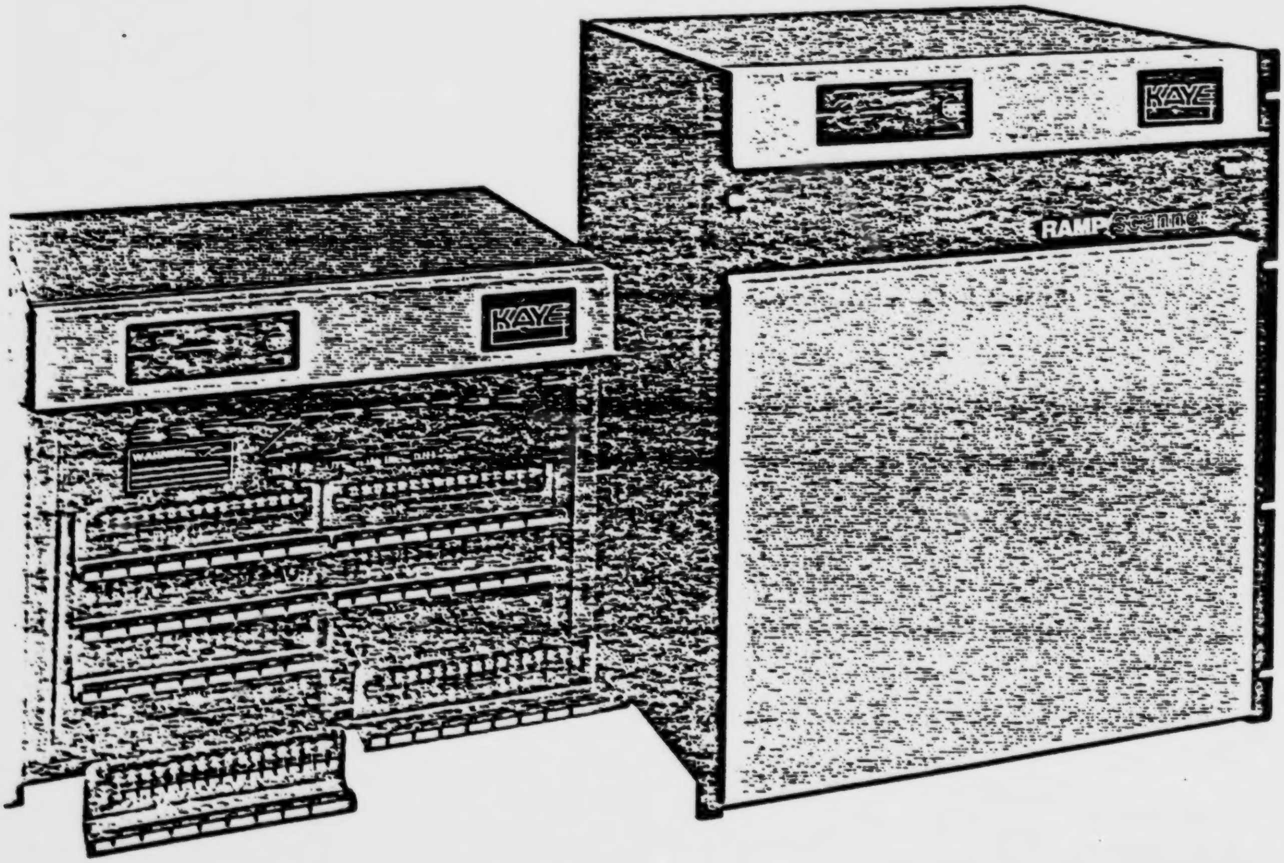
DIGISTRIP III...MORE POWER

The Math package in Digistrip II is an option. It is a standard feature in Digistrip III. What is more significant is the implementation of the Math Package in Digistrip III. Both Math Packages are implemented by assigning predefined function numbers to channel locations. Implicit in each math function number definition is the source location for the variables of the operation to be performed. With Digistrip II, transfer functions are widely used to align the data. With Digistrip III a source channel location is specified as part of the Function definition. This minor variation results in a significantly more compact program.

The calculated result of a math function is updated at least once every ten seconds with the result stored in the channel location where the math function number is assigned. The Math Packages provide a straight-forward means to accomplish a wide variety of calculations. Any channel location may have a math function number assigned to it. Thus all channel locations are usable with the Math Packages.

Standardization of the Math Package in Digistrip III results in several distinct operating advantages. Linear functions are now easily defined by X and Y coordinates. Auto-Calibration permits a user to make a linear scaling correction or calibration on any channel. This Auto-Calibration feature, which quickly builds in a unique individual linear correction factor for the channel, is a real time saver on critical measuring applications whether it is semiconductor processing, heat treating, or pharmaceutical validation. Hidden to the user, but of interest, are the curve fit routines used for linearizing the thermocouples and RTDs. These are no longer done with a series of linear segments; higher order terms are used now. The advantage is that fewer memory locations are required and fits are tighter.

$$w = C_0 \sqrt{\frac{P+14.69}{T+Ta} \Delta P}$$



WIRTANEN ELECTRIC [1962] LTD.

FLOWS AND PRESSURES

	IW 1959	Polysonic Flowmeter Model UFM-PD (Velocity-feet per second)	
*	IW 2764	Polysonic Flowmeter Model DHT-P (Velocity-feet per second/Dual Transducers)	USED AT CAMBRIDGE BAY
	IW 1663	Alnor Velometer Model 6000AP (Flow Velocities of air & Measures Static Pressure) Range 0/1250/2500/5000/10,000 FPM	
	IW 1863	Metermaster Portable Digital Anemometer Model 1717 (Air Velocity-Fan Type) Range 100 to 3000 FPM	
	IW 2314	Pitot Tube(14' tube c/w 3 outlets) (Measures Static Pressure, Temp, High Pressure)	
	IW 2233	Alnor Dewpoint Meter Model 7000U Range 10°F below room temperature to -80°F	
	IW 84	Welch Vacuum Pump Model 1-098 Vacuum .500005(5x10^{-5}) 33.4 Liters/min	
	IW 2235	Pressure/Vaccuum Pump Cat. #01-092-10 (Capacity 7 liters/min) Max. Pressure (14PSIG) Vacuum (36 CMHG)	
	IW 1028	Gast Vacuum Pump Model 0211 Vacuum 30"/Pressure 30PSIG	
	IW 2039	Taylor Pressure Calibrator Model 153S19, 0-18"	
	IW 2040	Taylor Pressure Calibrator Model 153S18, 0-160"	
	IW 648	Chandler Engineering Model #2-1 2000 lbs Dead Weight Tester	
	IW 507	Chandler Engineering Model #23-1 5000 lbs Dead Weight Tester	
	IW 1887	Chandler Engineering Model #55-1 15,000 lbs Dead Weight Tester	
	IW 1674	Wallace & Tiernen Model 65-120, Portable Pneumatic Calibrator Ranges -100" Water to +850" Water, -3.6 PSI to 30.6 PSI	

August 17, 1984

BULLETIN FS 379-2

P.S.E. Flow Sensor

USED AT CAMBRIDGE B

PSE, Inc.

28761 Maplewood • Garden City, Michigan 48135 • Phone: 313/422-5052

INTRODUCTION

The PSE Flow Sensor is an averaging pitot tube providing accurate, convenient flow rate sensing, promptly delivered, at an economical price.

Pitot tubes have been used in flow measurement for years. Conventional pitot tubes sense velocity (or impact) pressure at only one point in the flowing stream. Therefore, a series of pressures across the flowing stream must be measured to get a meaningful indication of flow rate. The PSE Flow Sensor eliminates this "traversing" the flowing line because of its double pressure averaging feature.

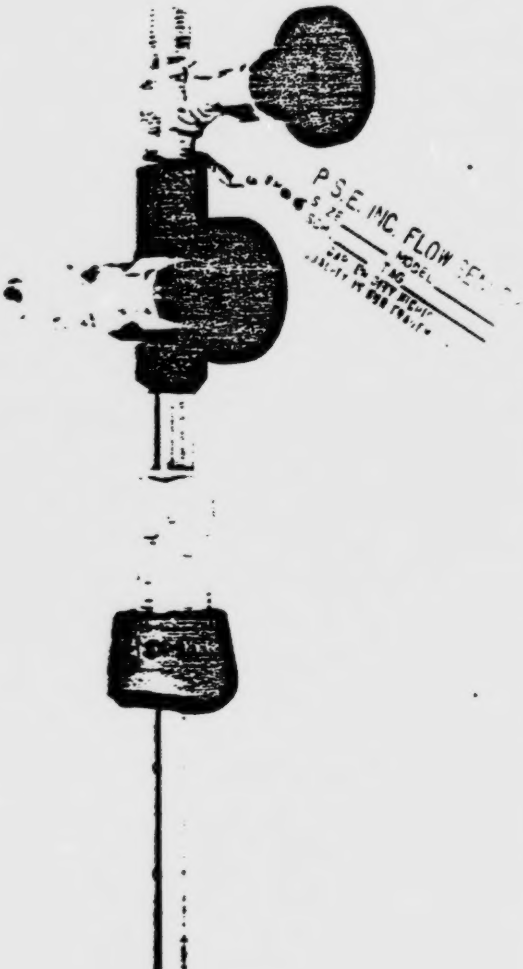
DESIGN

PSE uses two "D" shaped tubes within a tube to provide two separate pressure sensing tubes (one upstream, one down). This 3 tube (two within one) method creates a structurally strong sensing probe resistant to vibration and bending forces of the flowing fluid velocities. This rigid design assures proper positioning of the sensor in the flowing stream for best accuracy and repeatibility.

FEATURES

The PSE Flow Sensor minimizes pressure drop, thereby minimizing pumping costs. It is easy and inexpensive to install either in a new system or existing installation. The averaging of both up and down stream pressures makes "traversing" unnecessary.

The all 316 ss design provides versatility of process fluid compatibility. The smooth exterior sensor profile allows for easy insertion through a conventional packing gland arrangement.



P.S.E. Flow Sensor
6" Pipe Size

Bulletin AD-282

Accuracy
Flow Test Data

PSE, Inc.

41227 I-94 Expressway, South Service Drive • Van Buren Township, Belleville, Michigan 48111 • Phone: 313/697-0850

ACCURACY & FLOW TESTS PSE FLOW SENSORS

Summary

Competition has promoted accuracy of the shape of their sensor saying that the round shape is inherently less accurate. Predictable performance is determined by flow testing of an averaging pitot tube. The desire is to produce a sensor that has a linear flow coefficient over a wide range of flows.

PSE has tested a variety of sensor configurations to achieve the most linear coefficient possible.

TEST RESULTS INDICATE PSE HAS ACHIEVED THIS GOAL. The data and graphs of coefficient versus Reynolds Number on the following pages illustrate the superior performance of this new PSE design.

Accuracy — A Means of Comparison

Accuracy is often one of the parameters used in specifying, describing, or evaluating instruments. This seems logical.

However, we must understand what we mean by "accuracy" in order to be certain we are comparing "apples and apples" when we are evaluating accuracy statements made by various instrument manufacturers.

If you are a manufacturer/supplier of instruments, plus or minus 1% is an accuracy statement you'd like to be able to make. Therefore, it's good if you can come up with a statement that can be construed as plus or minus 1%. As a user, specifier, you want to be certain the statement is clear and based on solid data.

Accuracy — A Definition

Accuracy of a device should mean, "How close is the indication of this device to the true value?" Therefore, if a device is stated to have an accuracy of plus or minus 1%, it should mean that if it reads 50, the true value should be between 49.5 and 50.5.

In flowmeter accuracy, we need to know:

Can we calculate flow rate by formula and predict the reading or must we actually flow calibrate each device?

Flow Testing — Determining Flow Coefficient

In differential pressure type flow meters, flow tests must be conducted to determine the actual performance of the device compared to the theoretical. This relationship of actual to theoretical is expressed as a flow coefficient. This coefficient is used in the flow formula when doing flow calculations.

Flow Effects on Coefficient

Often the flow coefficient for a device will vary with changes in flow rate. For devices where this occurs, it can readily be seen that a **separate calculation must be made** for each flow rate using the appropriate coefficient for that flow rate.

Simply stated, Reynolds Number is a velocity index. Flow coefficient determination tests normally relate flow coefficient to Reynolds Number. Since the coefficient often changes in relation to Reynolds Number (velocity or flow rate) some manufacturers will use a "Reynolds Number Factor" in their flow calculations. It is obvious that for a device having a coefficient unaffected by Reynolds Number, no correction for change in Reynolds Number is required.

Flow Rate Effect on Differential Pressure Sensing

Differential pressure type flow devices are designed to provide accurate creation and sensing of differential pressure. The desire is to make the device so that the pressures sensed are not adversly affected or distorted. Averaging pitot tubes sense total pressure (velocity + static) upstream and static pressure downstream.

Vortex shedding can effect the downstream pressure when it is sensed on the downstream face of the sensor. As the velocity changes, the frequency of the vortex shedding changes. Also, the point on the surface of the sensor where the shedding occurs changes. It is this phenomenon that affects the downstream static pressure and causes a change in the flow coefficient. This is what causes the need for a "Reynolds Number Factor" to correct for effects of changes in velocity.

FOR GENERAL INDUSTRIAL NEEDS

FLOW EQUATION FOR WATER
(AND/OR ANY LIQUID)

LIQUID VOLUME FLOW RATE: (GPM)

$$K \times N \times D^2 \times \sqrt{\frac{1}{S_G}} = Y$$

$$Y \times \sqrt{\Delta P} = Q$$

$$\left(\frac{Q}{Y}\right)^2 = \Delta P$$

K = FLOW COEFFICIENT (SEE TABLE 1, PAGE 5)

N = CORRECTION FACTOR DEPENDS ON UNITS OF MEASUREMENT USING GPM AND (ΔP) INCHES OF WATER. N = 5.666

D = EXACT INSIDE DIAMETER OF PIPE IN INCHES

S_G = SPECIFIC GRAVITY OF LIQUID AT FLOW CONDITIONS

Y = THE NUMERICAL VALUE IS THE PRODUCT OF THE APPROPRIATE FACTORS FOR THAT EQUATION ONLY

ΔP = PRESSURE DIFFERENTIAL OF FLOW SENSOR IN INCHES OF WATER

Q = VOLUME FLOW RATE IN GPM

PSE, Inc.

PA

41227 I-94 X-Way Service Drive • Van Buren Township • Belleville MI 48111 • (313) 697-0850

FOR GENERAL INDUSTRIAL NEEDS

FLOW EQUATION FOR ANY GAS

GAS VOLUME FLOW RATE: (SCFM)

$$K \times N \times D^2 \times \sqrt{\frac{A_P}{A_T \times S_W}} = Y$$

$$Y \times \sqrt{\Delta P} = Q$$

$$\left(\frac{Q}{Y}\right)^2 = \Delta P$$

K = FLOW COEFFICIENT (SEE TABLE 1, PAGE 5)

N = CORRECTION FACTOR DEPENDS ON UNITS OF MEASUREMENT USING SCFM AND (ΔP) INCHES OF WATER. $N = 35.59$

D = EXACT INSIDE DIAMETER OF PIPE IN INCHES

A_P = ABSOLUTE PRESSURE: ATMOSPHERIC PRESSURE MUST BE ADDED TO THE GAGE PRESSURE (SEE TABLE 2, PAGE 6)

A_T = ABSOLUTE TEMPERATURE: ADD 460 TO DEGREES FAHRENHEIT TO EQUAL DEGREES RANKINE

S_W = SPECIFIC GRAVITY AT FLOW CONDITIONS x .0764 (AIR AT STD. COND.)

Y = THE NUMERICAL VALUE IS THE PRODUCT OF THE APPROPRIATE FACTORS FOR THAT EQUATION ONLY

ΔP = PRESSURE DIFFERENTIAL OF FLOW SENSOR IN INCHES OF WATER

Q = VOLUME FLOW RATE IN SCFM

FILE NO. 382-3

PSE, Inc.

41227 I-94 X-Way Service Drive • Van Buren Township • Belleville, MI 48111 • (313) 697-0850

TABLE 1
FLOW COEFFICIENTS (K)

THE FOLLOWING COEFFICIENT VALUES ARE FOR CONVENTIONAL PSE FLOW SENSORS (NOT PAR. 70 UNITS)

FPS = AVERAGE VELOCITY FT./SEC. (WATER)

PIPE SIZE	FPS	K	FPS	K	FPS	K	FPS	K
3/4"	1-5.9	.425	6-9.9	.440	10-15.9	.460	16)	.470
1"	1-5.9	.537	6-11.9	.555	12-15.9	.575	16)	.595
1-1/4"	1-5.9	.547	6-11.9	.565	12-21.9	.575	22)	.585
1-1/2"	1-5.9	.557	6-11.9	.567	12-21.9	.580	22)	.590
2"	2-3.9	.585	4-18.9	.595	19)	.605		
2-1/2"	2-13.9	.617	14-19.9	.635	20)	.647		
3"	2-11.9	.630	12-17.9	.640	18)	.650		
4"		.670						
5"	2-19.9	.680	20)	.695				
6"	2-15.9	.667	16)	.680				
8"		.672						
10"		.694						
12"		.702						
14"		.705						
16"		.706						
18"		.707						
20"		.717						
24"		.723						
30"		.724						
36"		.725						
42"		.726						
48"		.729						
60"		.738						
72"		↓						
100"		↓						
144"		↓						

THE FOLLOWING COEFFICIENT VALUES ARE FOR PAR-70 PSE FLOW SENSORS

PIPE SIZE	K
2"	.615
2-1/2"	.630
3"	.640
4"	.648
5"	.620
6"	.637
8"	.645
10"	.636
12"	.627
14"	.625
16"	.623
18"	.620
20"	.617
24"	.616

APPENDIX "C-2"

MONITORED DATA

Temperature, pressure and flow data of the exhaust gases and jacket water from the diesel engines at Lac La Martre and Cambridge Bay are available from the Department of Public Works of the Government of the Northwest Territories.

APPENDIX "C-3"

LAC LA MARTRE PLATE HEAT EXCHANGER DESIGN PARAMETERS

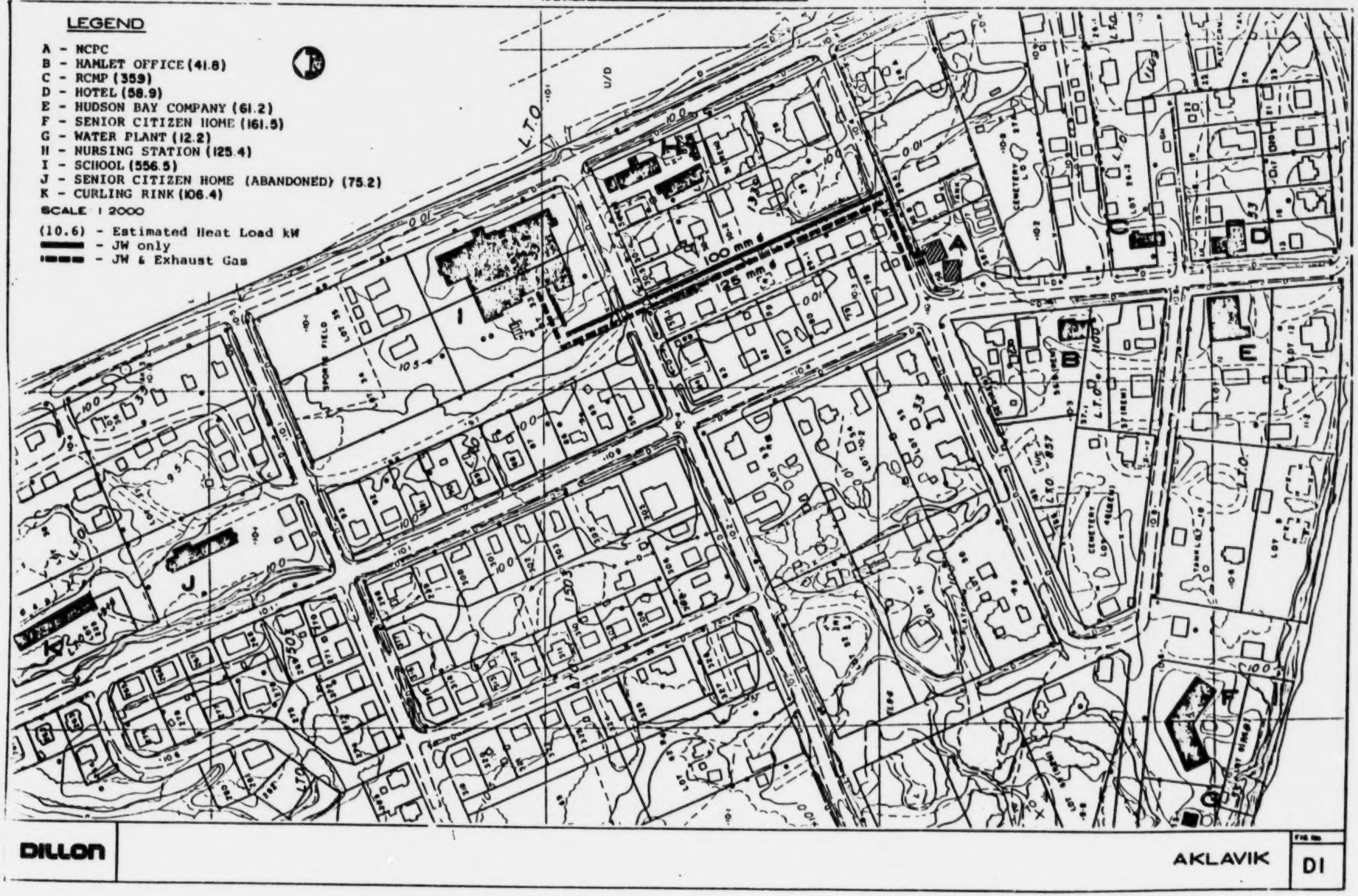
Heat Exchanger - Vicarb SA Type V28S57, manufactured by Nixon Plate Coils in Formley, Ontario
(416) 727-3166

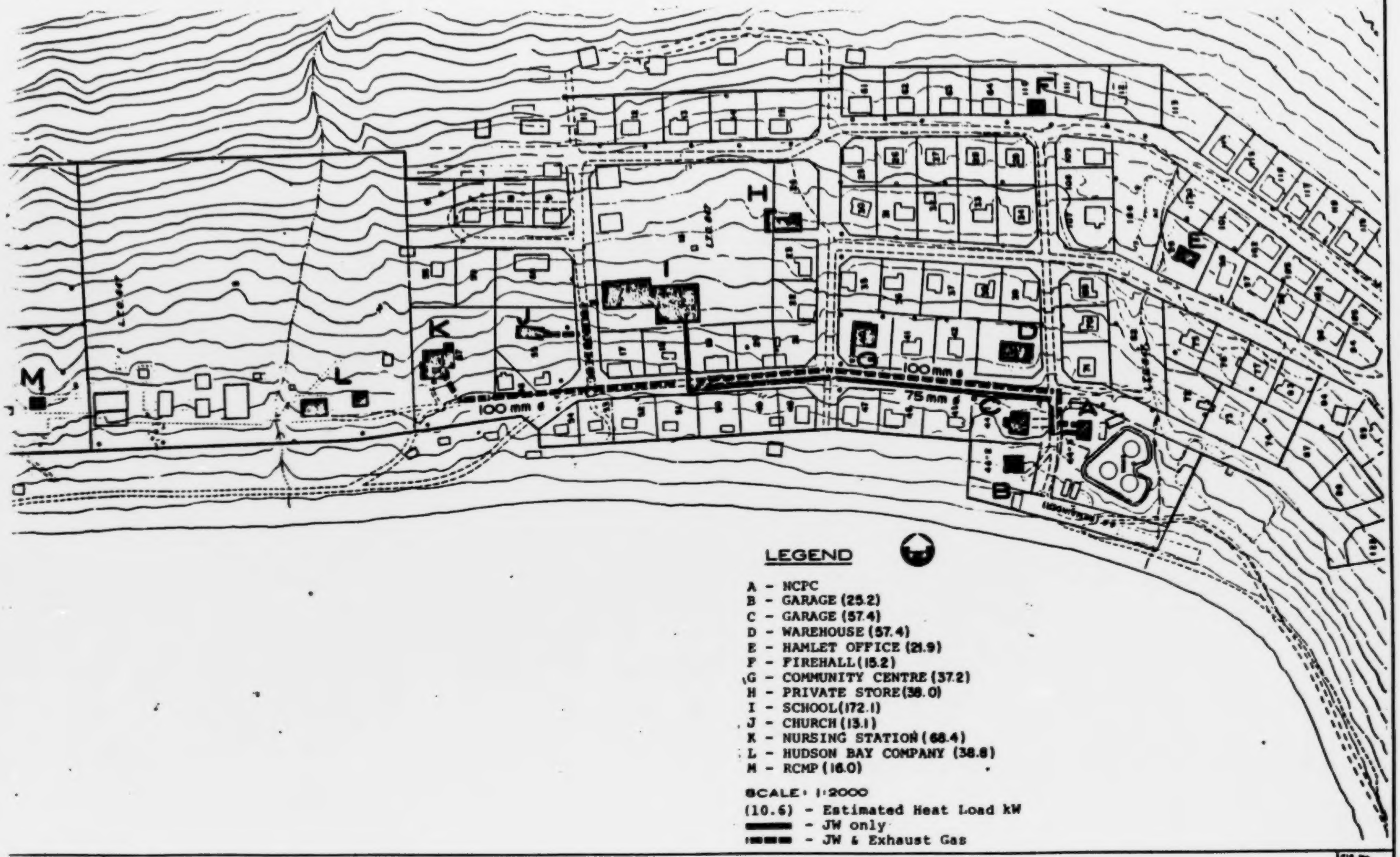
- Date of manufacture: 1981
- P.O. No. 19902
- Drawing No. NAV 8304-1
- No. of Plates: 31
- Maximum No. of Plates which can be installed: 55
- Primary Side
  - Design for 60% glycol
  - 51,744 lb/hr
  - T_{in} 185°F
  - T_{out} 170°F
  - Pressure Drop 1.18 psi
- Secondary Side
  - Design for 6% glycol
  - 37,780 lb/hr
  - T_{in} 140°F
  - T_{out} 160°F
  - Pressure Drop 4.56 psi

Manufacturer advises that an additional 24 plates can be installed on this HX for a total of 55. This would reduce the temperature difference from the present 26°F to 17°F. To go to a temperature difference of 9°F requires a new HX with 75 plates. Cost of supplying plates and gaskets to upgrade existing HX is $2,230.

APPENDIX "D-1"

SITE PLAN OF DISTRICT HWS DISTRIBUTION SYSTEM AND BUILDING HEAT LOSSES


LEGEND
A - NCPC
B - HAMLET OFFICE (41.8)
C - RCMP (359)
D - HOTEL (58.9)
E - HUDSON BAY COMPANY (61.2)
F - SENIOR CITIZEN HOME (161.5)
G - WATER PLANT (12.2)
H - NURSING STATION (125.4)
I - SCHOOL (556.5)
J - SENIOR CITIZEN HOME (ABANDONED) (75.2)
K - CURLING RINK (106.4)
SCALE 1 2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
100 mm ø
125 mm ø
L.T.O
U/D
CEMETERY
SPORTS FIELD
A
B
C
D
E
F
G
H
I
J
K
DILLON
AKLAVIK
D1

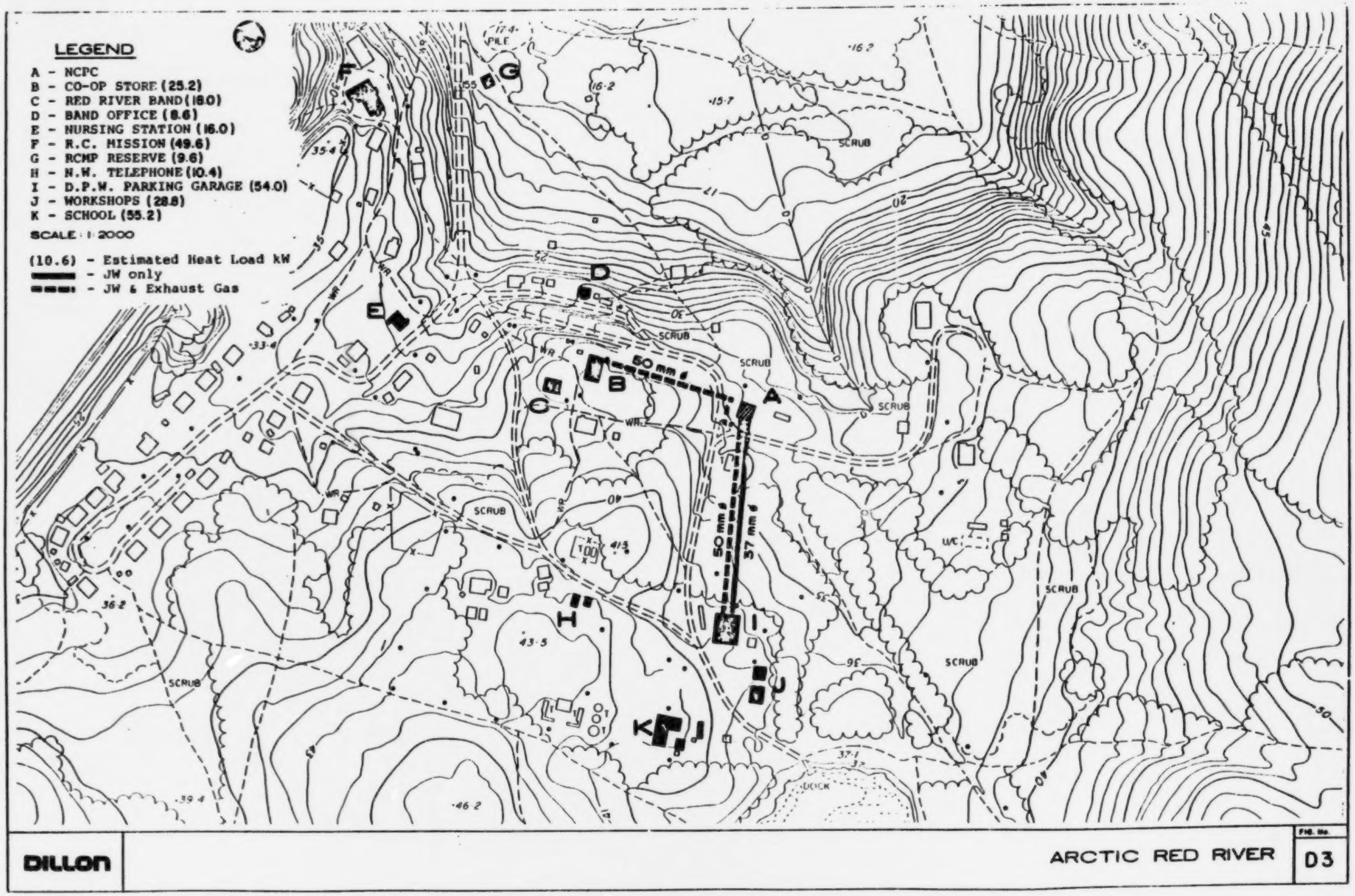

M
L
K
J
I
H
G
F
E
D
C
B
A
100 mm ø
100 mm ø
75 mm ø

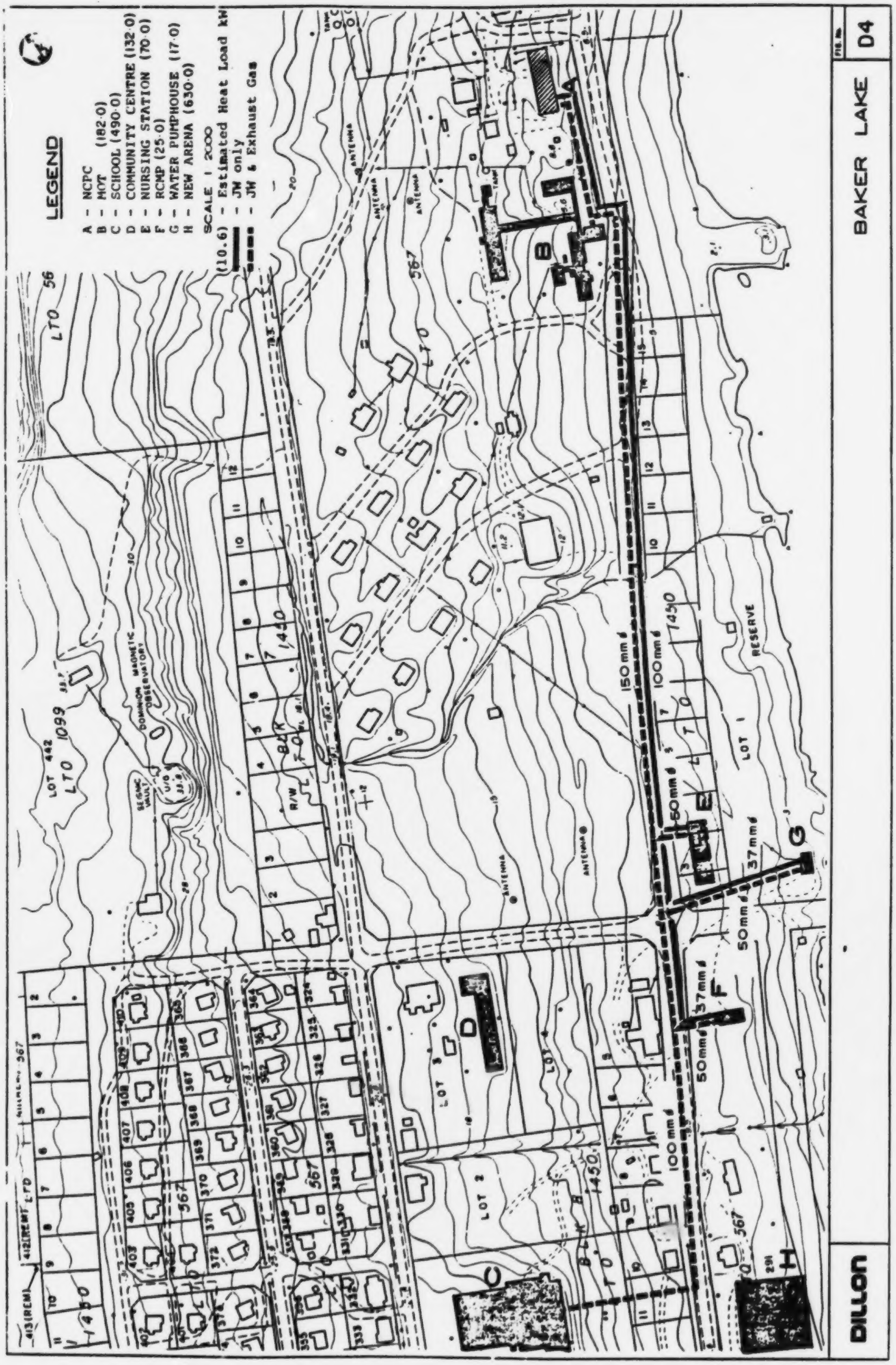
LEGEND

A - NCPC
B - GARAGE (25.2)
C - GARAGE (57.4)
D - WAREHOUSE (57.4)
E - HAMLET OFFICE (21.9)
F - FIREHALL (15.2)
G - COMMUNITY CENTRE (37.2)
H - PRIVATE STORE (38.0)
I - SCHOOL (172.1)
J - CHURCH (13.1)
K - NURSING STATION (68.4)
L - HUDSON BAY COMPANY (38.8)
M - RCMP (16.0)

SCALE: 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ - JW & Exhaust Gas

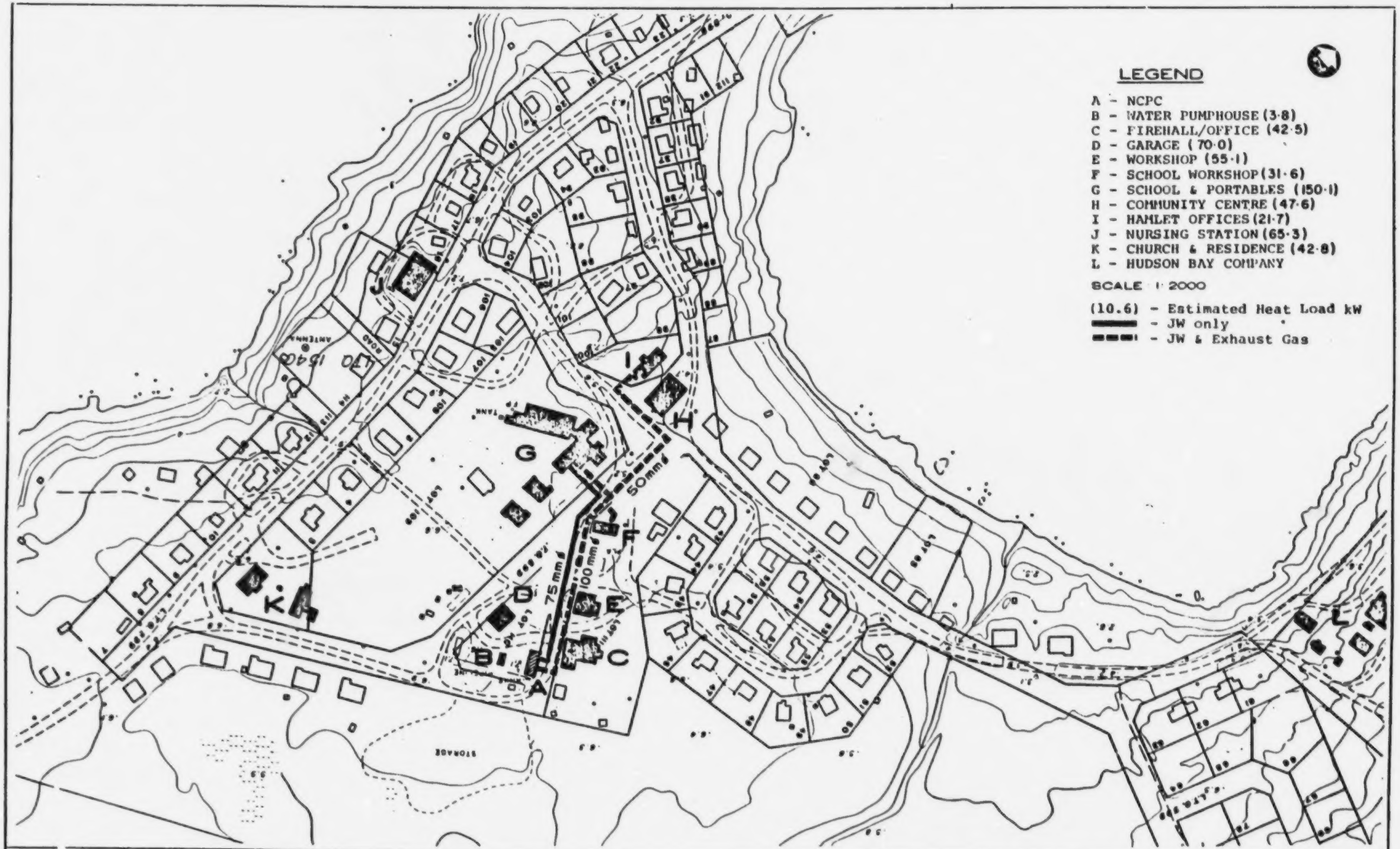
DILLON	ARCTIC BAY	FIG. No. D2


LEGEND
A - NCPC
B - CO-OP STORE (25.2)
C - RED RIVER BAND (18.0)
D - BAND OFFICE (8.6)
E - NURSING STATION (16.0)
F - R.C. MISSION (49.6)
G - RCMP RESERVE (9.6)
H - N.W. TELEPHONE (10.4)
I - D.P.W. PARKING GARAGE (54.0)
J - WORKSHOPS (28.8)
K - SCHOOL (55.2)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
50 mm ⌀
50 mm ⌀
37 mm ⌀
SCRUB
PILE
DOCK
DILLON
ARCTIC RED RIVER
FIG. No.
D3


LEGEND
A - NCPC (182·0)
B - MOT
C - SCHOOL (490·0)
D - COMMUNITY CENTRE (132·0)
E - NURSING STATION (70·0)
F - RCMP (25·0)
G - WATER PUMPHOUSE (17·0)
H - NEW ARENA (630·0)
SCALE 1 2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
A
B
C
D
E
F
G
H
150mm ⌀
100mm ⌀
50mm ⌀
37mm ⌀
LTO 1099
LOT 492
LTO 56
DOMINION MAGNETIC OBSERVATORY
SEISMIC VAULT
RESERVE
LOT 1
LOT 2
LOT 3
LOT 4
ANTENNA
1450
567
DILLON

BAKER LAKE

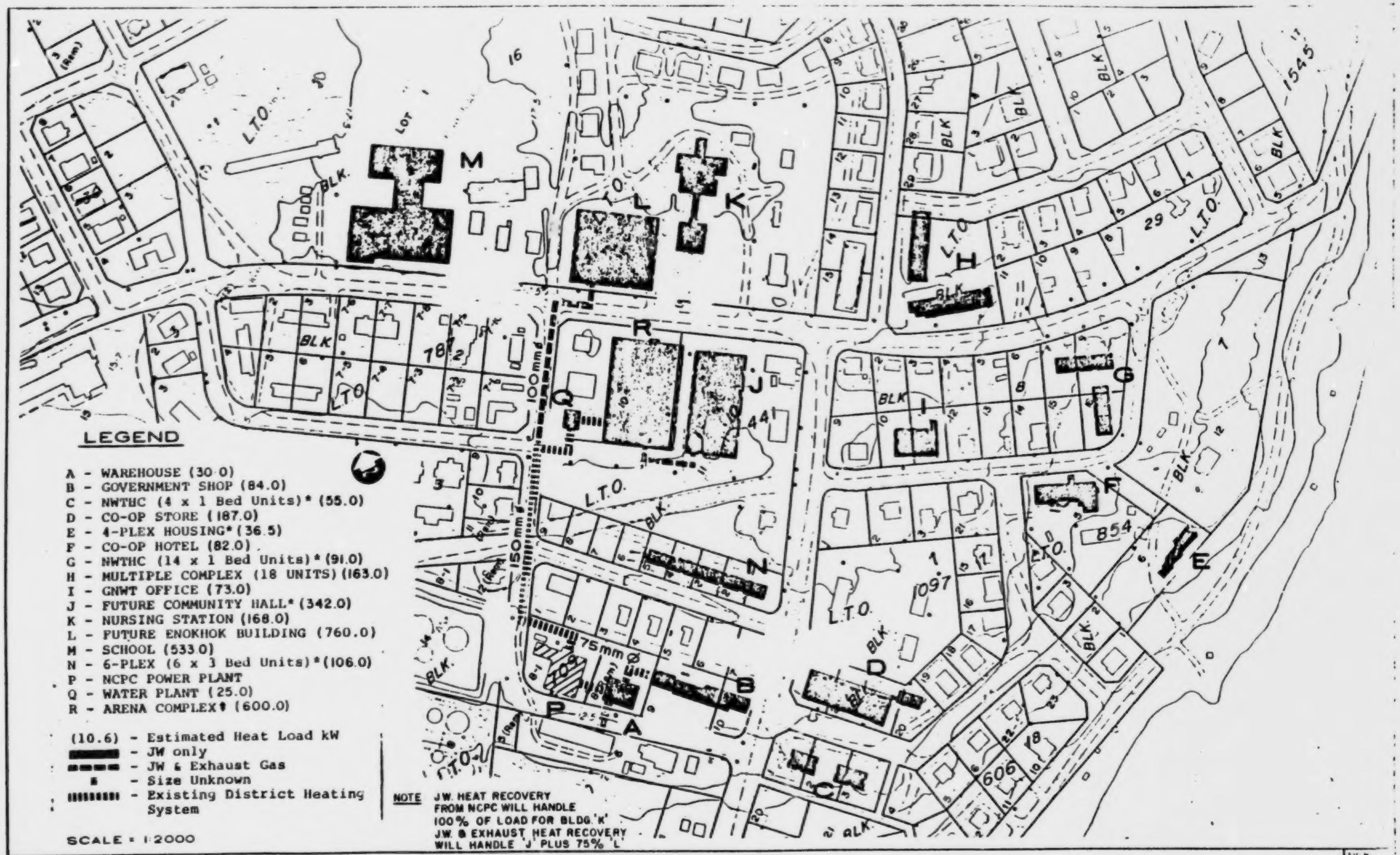
FIG. No. D4


LEGEND
A - NCPC
B - WATER PUMPHOUSE (3·8)
C - FIREHALL/OFFICE (42·5)
D - GARAGE (70·0)
E - WORKSHOP (55·1)
F - SCHOOL WORKSHOP (31·6)
G - SCHOOL & PORTABLES (150·1)
H - COMMUNITY CENTRE (47·6)
I - HAMLET OFFICES (21·7)
J - NURSING STATION (65·3)
K - CHURCH & RESIDENCE (42·8)
L - HUDSON BAY COMPANY
SCALE 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
╍ - JW & Exhaust Gas
50mm ø
100mm ø
75mm ø
TANK
STORAGE
ANTENNA
A
B
C
D
E
F
G
H
I
J
K
L

DILLON

BROUGHTON ISLAND

FIG No D5


M
L
K
H
R
J
G
I
Q
F
E
N
D
B
P
A
C
BLK
L.T.O.
LOT 1
100mmø
150mmø
75mmø
1545
29
787
441
854
1097
606
16

LEGEND

A - WAREHOUSE (30.0)
B - GOVERNMENT SHOP (84.0)
C - NWTHC (4 x 1 Bed Units)* (55.0)
D - CO-OP STORE (187.0)
E - 4-PLEX HOUSING* (36.5)
F - CO-OP HOTEL (82.0)
G - NWTHC (14 x 1 Bed Units)* (91.0)
H - MULTIPLE COMPLEX (18 UNITS) (163.0)
I - GNWT OFFICE (73.0)
J - FUTURE COMMUNITY HALL* (342.0)
K - NURSING STATION (168.0)
L - FUTURE ENOKHOK BUILDING (760.0)
M - SCHOOL (533.0)
N - 6-PLEX (6 x 3 Bed Units)* (106.0)
P - NCPC POWER PLANT
Q - WATER PLANT (25.0)
R - ARENA COMPLEX* (600.0)

(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
▪ - Size Unknown
▮▮▮▮ - Existing District Heating System

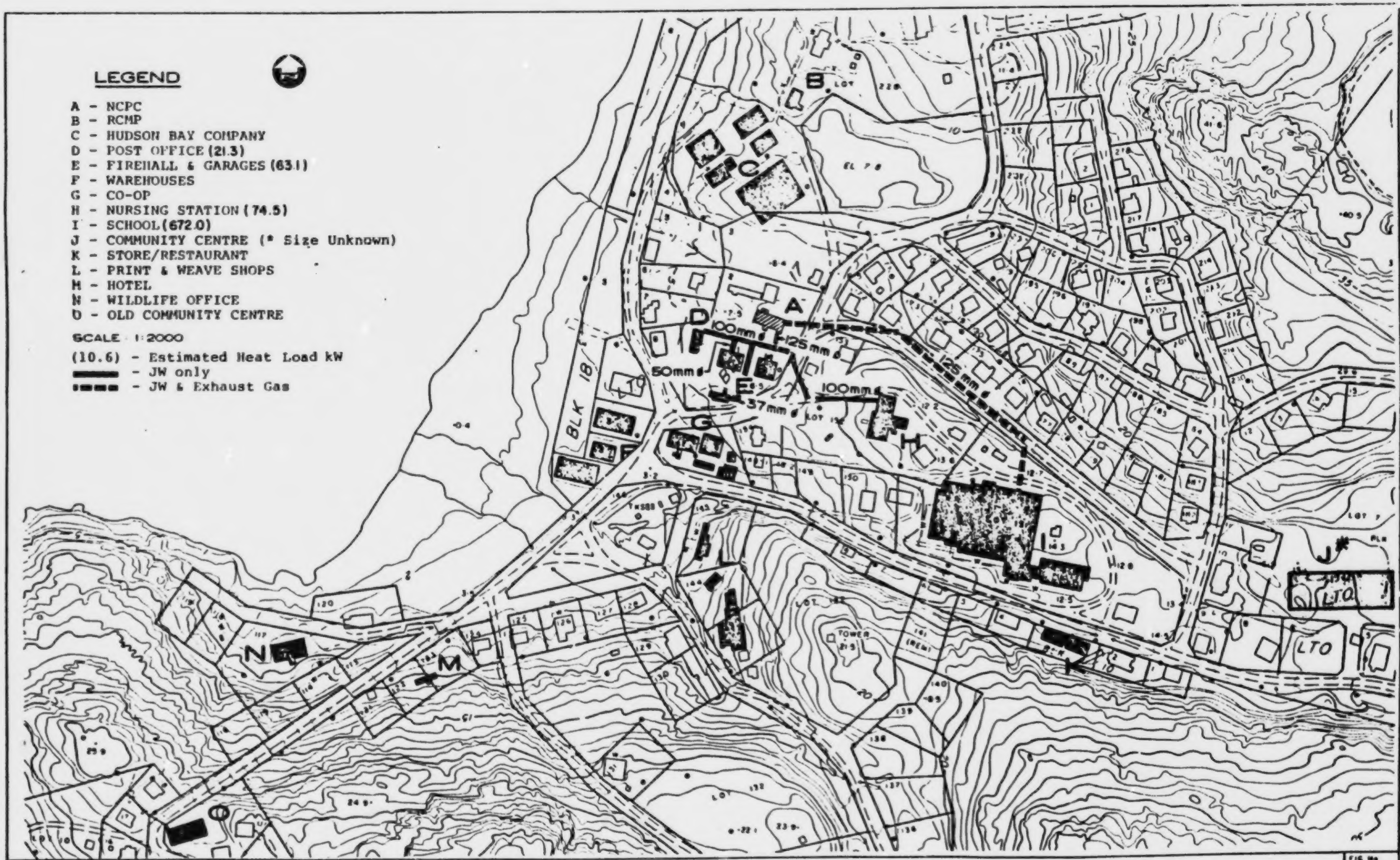
SCALE = 1:2000

NOTE J.W. HEAT RECOVERY FROM NCPC WILL HANDLE 100% OF LOAD FOR BLDG 'K'. J.W. & EXHAUST HEAT RECOVERY WILL HANDLE 'J' PLUS 75% 'L'

DILLON

CAMBRIDGE BAY

FIG. D6


A
B
C
D
E
G
H
I
J
K
M
N
O
100mm
125mm
125mm
50mm
37mm
100mm
BLK 18
LTO
TOWER

LEGEND

A - NCPC
B - RCMP
C - HUDSON BAY COMPANY
D - POST OFFICE (21.3)
E - FIREHALL & GARAGES (63.1)
F - WAREHOUSES
G - CO-OP
H - NURSING STATION (74.5)
I - SCHOOL (672.0)
J - COMMUNITY CENTRE (* Size Unknown)
K - STORE/RESTAURANT
L - PRINT & WEAVE SHOPS
M - HOTEL
N - WILDLIFE OFFICE
O - OLD COMMUNITY CENTRE

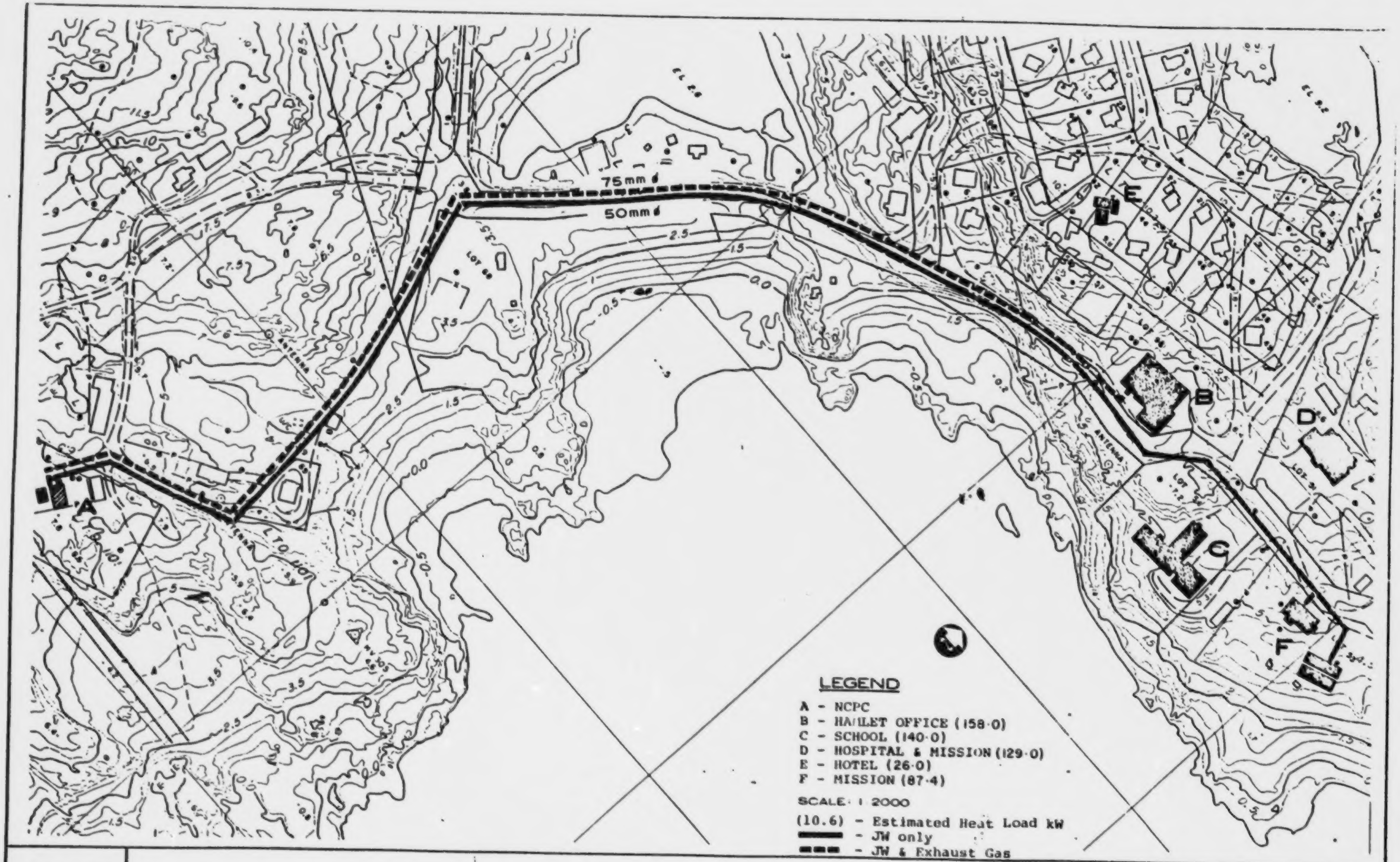
SCALE 1:2000

(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas

DILLON

CAPE DORSET

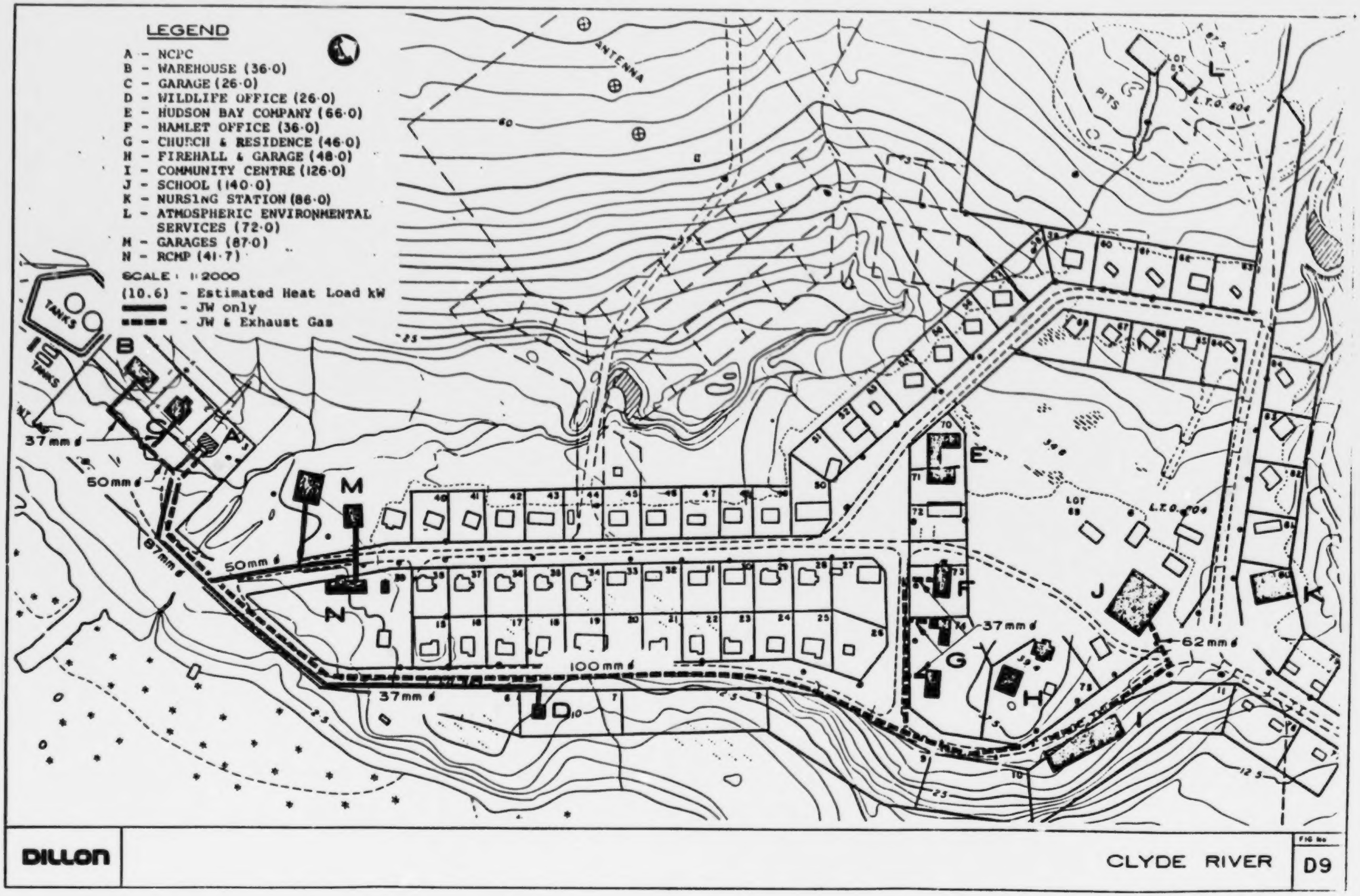
FIG No.
D7

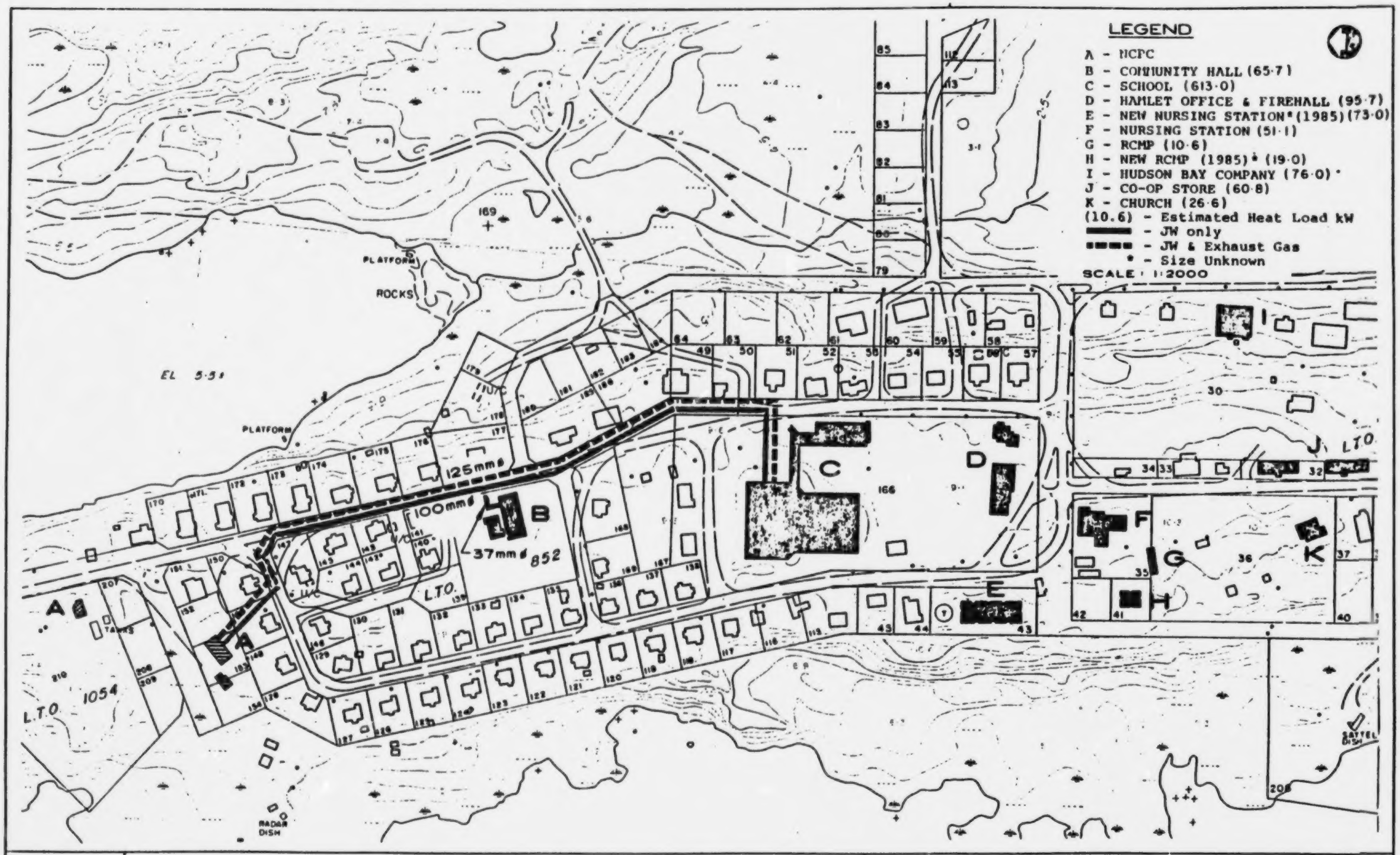

75mm ⌀
50mm ⌀
A
B
C
D
E
F
LOT 98
LOT 91
ANTENNA
EL 2.6
EL 8.2
LEGEND
A - NCPC
B - HAMLET OFFICE (158·0)
C - SCHOOL (140·0)
D - HOSPITAL & MISSION (129·0)
E - HOTEL (26·0)
F - MISSION (87·4)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas

DILLON

CHESTERFIELD INLET

FIG No D8

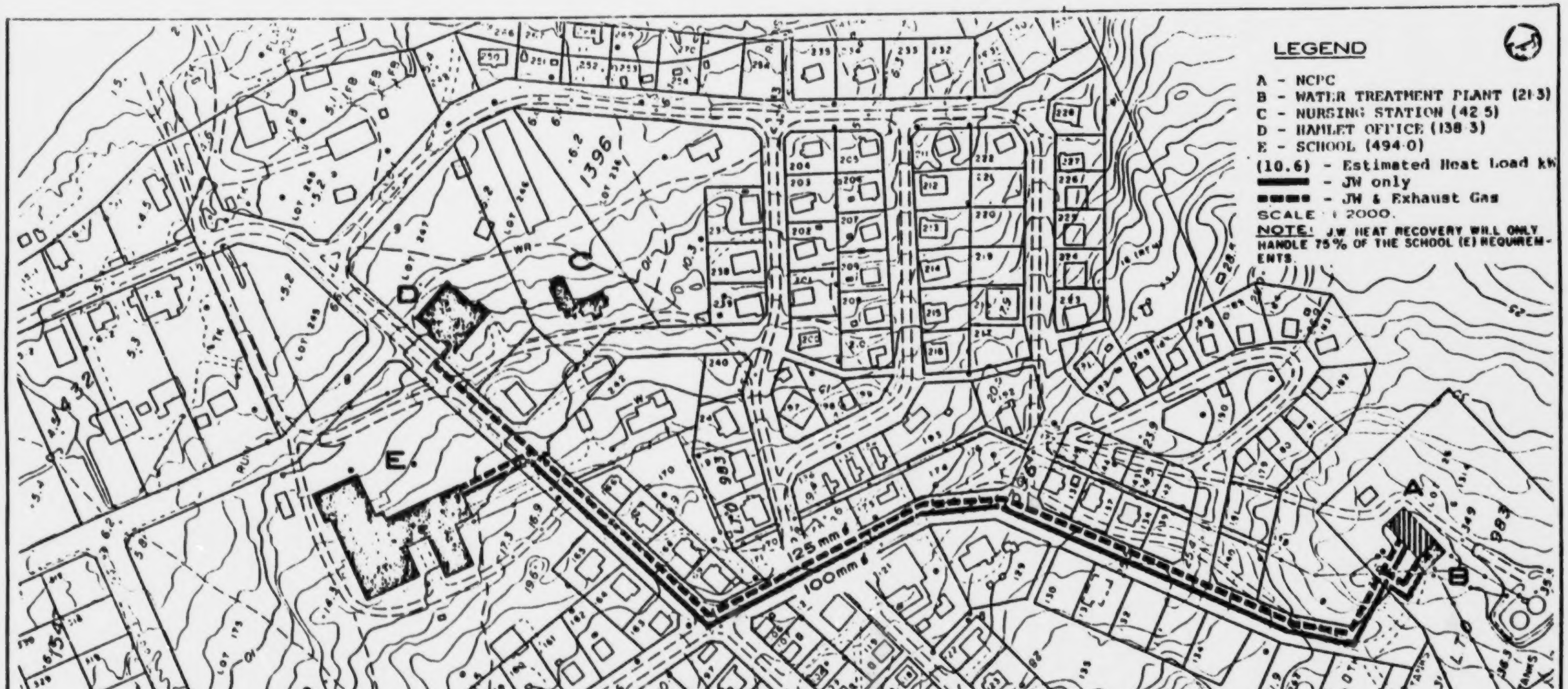

LEGEND
A - NCPC
B - WAREHOUSE (36·0)
C - GARAGE (26·0)
D - WILDLIFE OFFICE (26·0)
E - HUDSON BAY COMPANY (66·0)
F - HAMLET OFFICE (36·0)
G - CHURCH & RESIDENCE (46·0)
H - FIREHALL & GARAGE (48·0)
I - COMMUNITY CENTRE (126·0)
J - SCHOOL (140·0)
K - NURSING STATION (86·0)
L - ATMOSPHERIC ENVIRONMENTAL SERVICES (72·0)
M - GARAGES (87·0)
N - RCMP (41·7)
SCALE : 1:2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
TANKS
TANKS
ANTENNA
PITS
LOT 55
L.T.O. 404
LOT 69
L.T.O. 404
37mm ø
50mm ø
87mm ø
50mm ø
100mm ø
37mm ø
37mm ø
62mm ø
A
B
C
D
E
F
G
H
I
J
K
L
M
N
DILLON
CLYDE RIVER
FIG No
D9

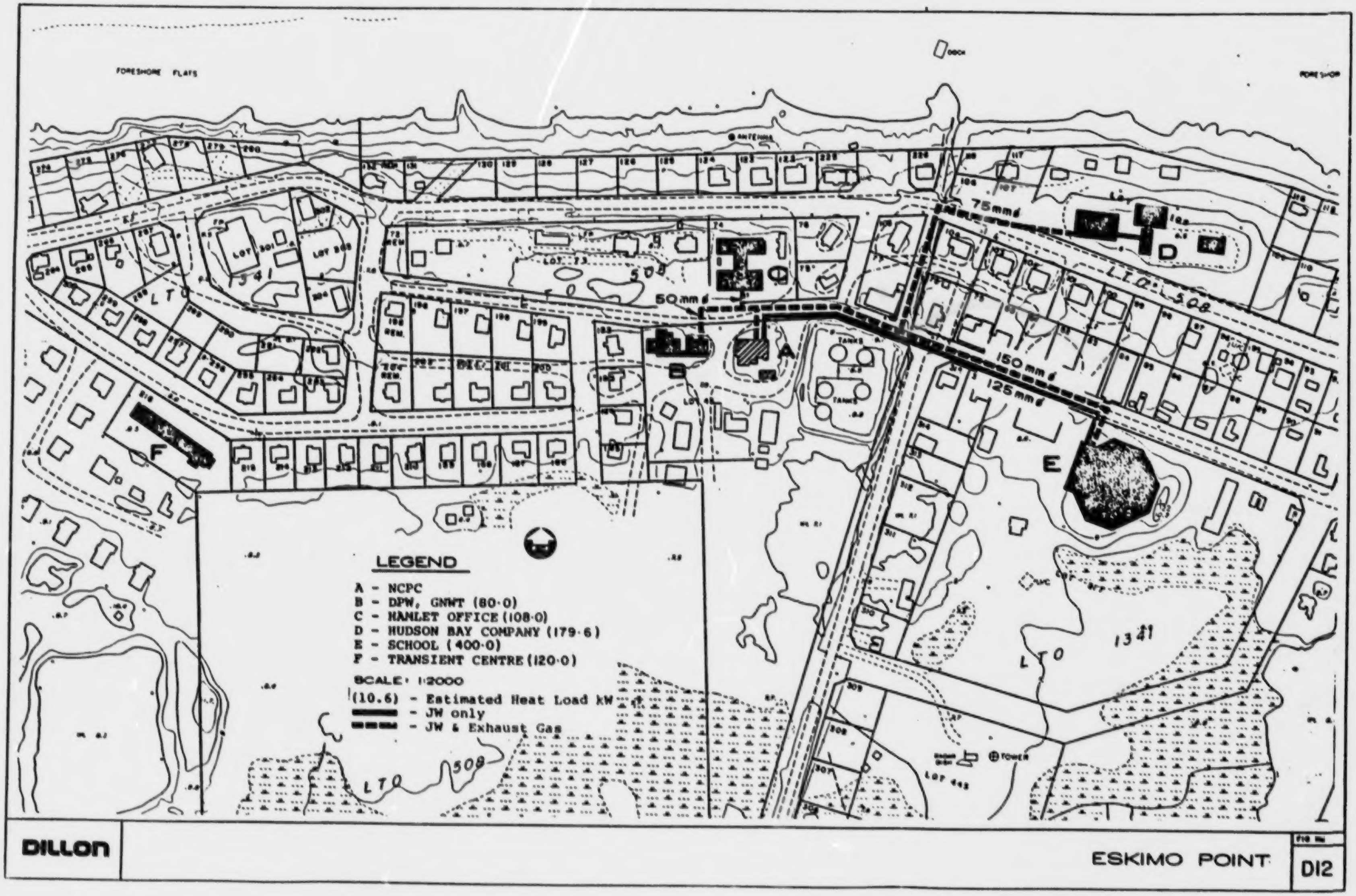

LEGEND
A - NCPC
B - COMMUNITY HALL (65·7)
C - SCHOOL (613·0)
D - HAMLET OFFICE & FIREHALL (95·7)
E - NEW NURSING STATION* (1985) (73·0)
F - NURSING STATION (51·1)
G - RCMP (10·6)
H - NEW RCMP (1985)* (19·0)
I - HUDSON BAY COMPANY (76·0)*
J - CO-OP STORE (60·8)
K - CHURCH (26·6)
(10.6) - Estimated Heat Load kW
▬ - JW only
▬▬ - JW & Exhaust Gas
* - Size Unknown
SCALE 1:2000
125mmø
100mmø
37mmø
852
1054
L.T.O.
EL 5·5±
PLATFORM
ROCKS
RADAR DISH
SATTEL DISH
A
B
C
D
E
F
G
H
I
J
K

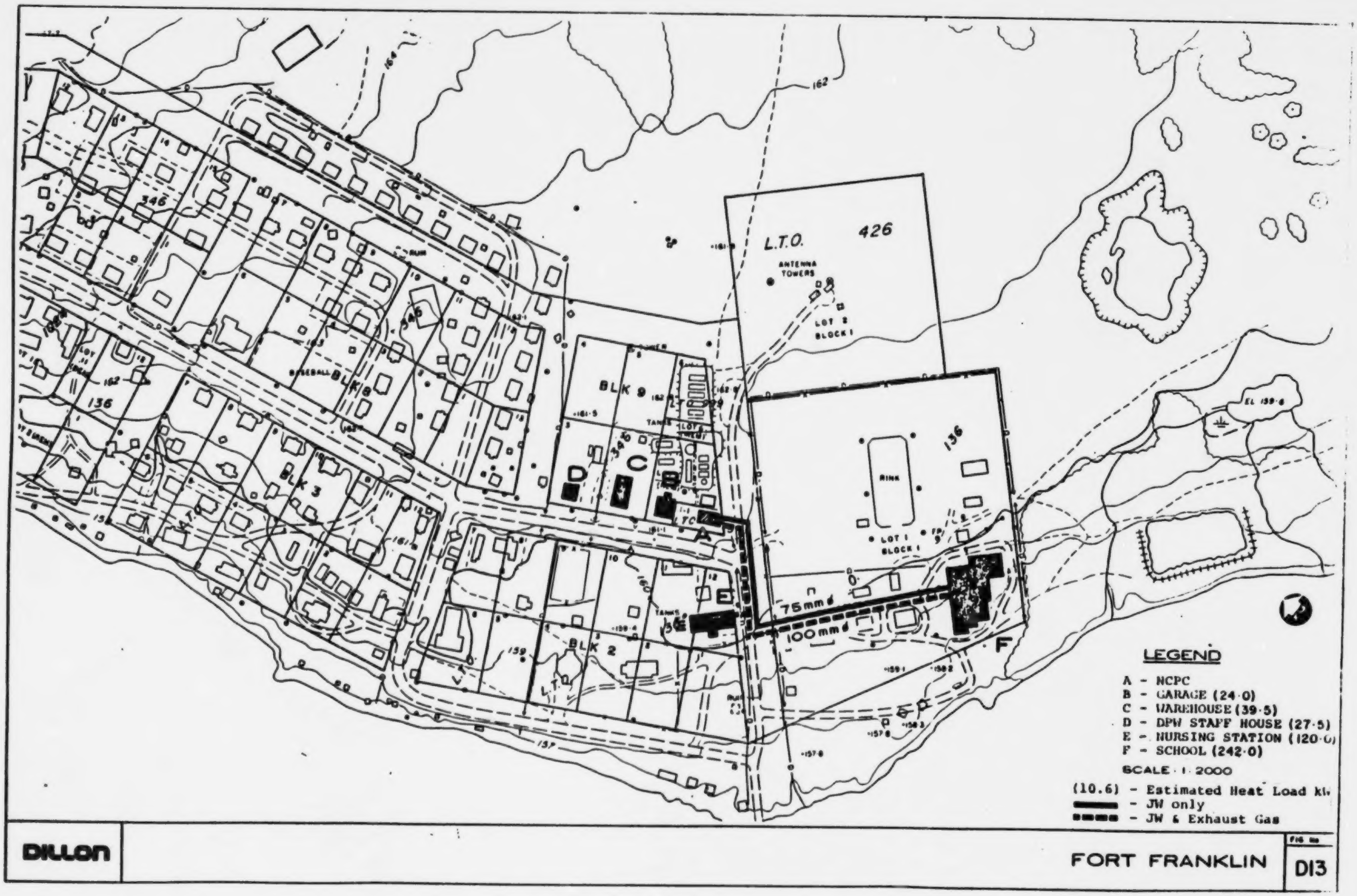
DILLON

CORAL HARBOUR

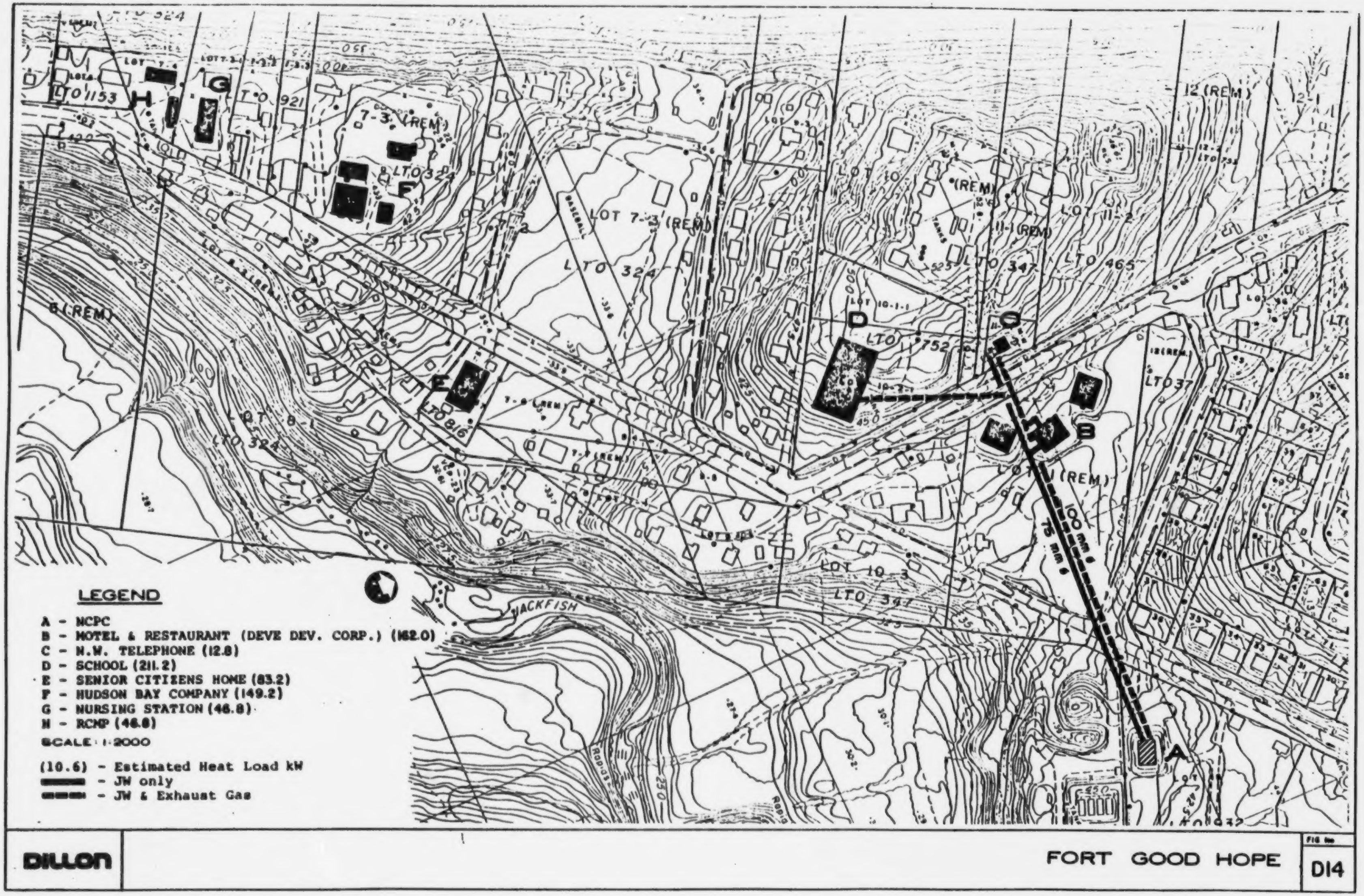
FIG. No D11

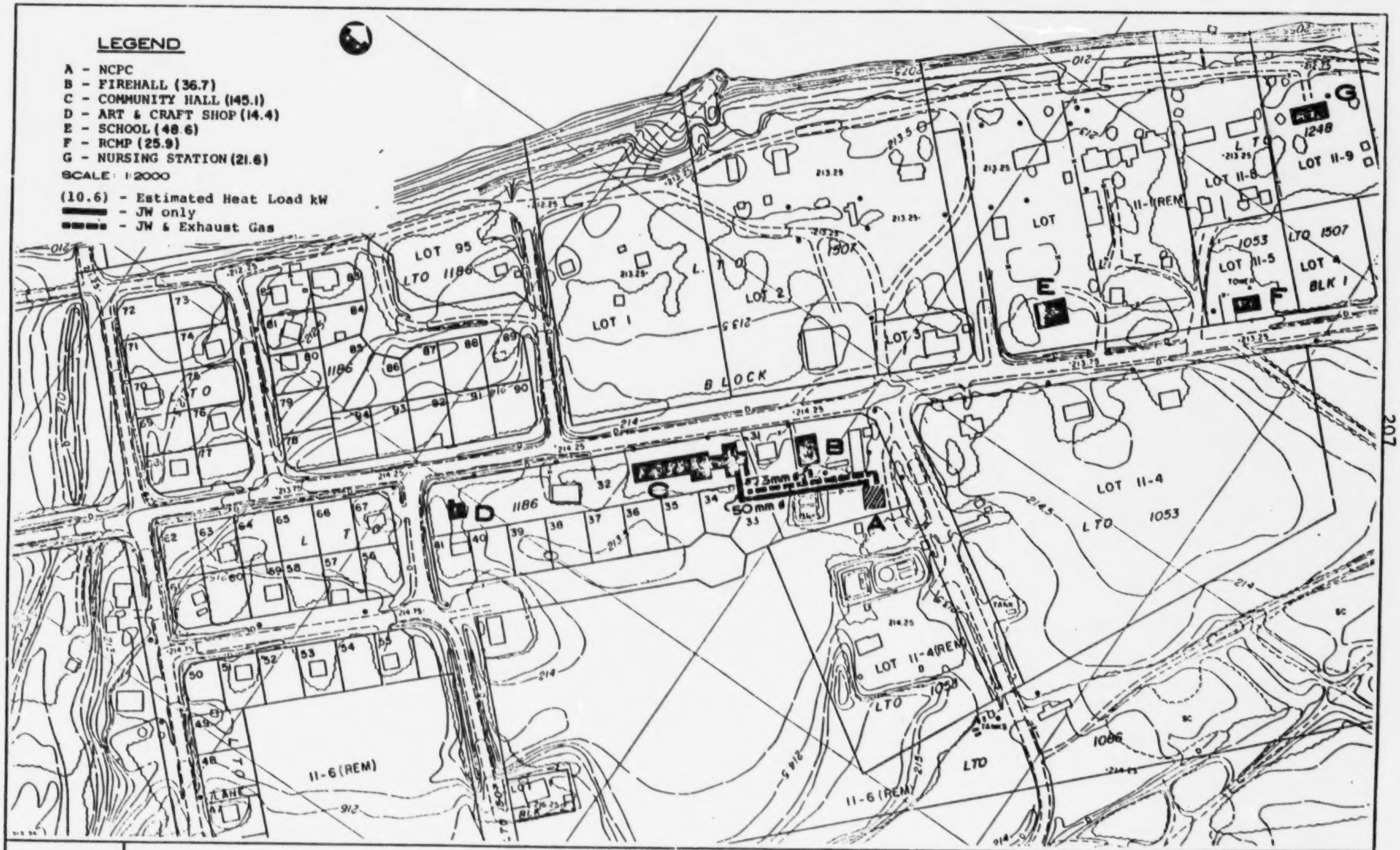

LEGEND
A - NCPC
B - WATER TREATMENT PLANT (21·3)
C - NURSING STATION (42 5)
D - HAMLET OFFICE (138 3)
E - SCHOOL (494·0)
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
SCALE 1 2000.
NOTE: J.W HEAT RECOVERY WILL ONLY HANDLE 75% OF THE SCHOOL (E) REQUIREMENTS.
A
B
C
D
E
125mm
100mm
1396
983
DILLON
COPPERMINE
D10


FORESHORE FLATS
FORESHORE
DOCK
ANTENNA
75mmø
50mmø
150mmø
125mmø
LTO 508
LTO 1341
LOT 301
LOT 302
LOT 73
LOT 443
TANKS
TOWER
A
B
C
D
E
F
LEGEND
A - NCPC
B - DPW, GNWT (80·0)
C - HAMLET OFFICE (108·0)
D - HUDSON BAY COMPANY (179·6)
E - SCHOOL (400·0)
F - TRANSIENT CENTRE (120·0)
SCALE: 1:2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
DILLON
ESKIMO POINT
FIG No
D12


L.T.O.
426
ANTENNA TOWERS
LOT 2 BLOCK 1
136
RINK
LOT 1 BLOCK 1
BLK 9
BLK 8
BLK 3
BLK 2
346
345
136
162
75mmø
100mmø
A
B
C
D
E
F
EL 139·6
LEGEND
A - NCPC
B - GARAGE (24·0)
C - WAREHOUSE (39·5)
D - DPW STAFF HOUSE (27·5)
E - NURSING STATION (120·0)
F - SCHOOL (242·0)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
DILLON
FIG No
D13

FORT FRANKLIN


LEGEND
A - NCPC
B - MOTEL & RESTAURANT (DEVE DEV. CORP.) (162.0)
C - N.W. TELEPHONE (12.8)
D - SCHOOL (211.2)
E - SENIOR CITIZENS HOME (83.2)
F - HUDSON BAY COMPANY (149.2)
G - NURSING STATION (46.8)
H - RCMP (46.8)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ - JW & Exhaust Gas
100 mm ø
75 mm ø
A
B
C
D
E
F
G
H
LTO 1153
LTO 921
7-3 (REM)
LTO 324
LOT 7-3 (REM)
BASEBALL
LTO 324
LOT 10
(REM)
11-1 (REM)
LOT 11-2
LTO 347
LTO 465
12 (REM)
LTO 752
LTO 37
LOT 8-1
LTO 324
8 (REM)
LTO 816
LOT 10-3
LTO 347
(REM)
HACKFISH
DILLON
FORT GOOD HOPE
FIG No
D14



LEGEND

A - NCPC
B - FIREHALL (36.7)
C - COMMUNITY HALL (145.1)
D - ART & CRAFT SHOP (14.4)
E - SCHOOL (48.6)
F - RCMP (25.9)
G - NURSING STATION (21.6)

SCALE: 1:2000

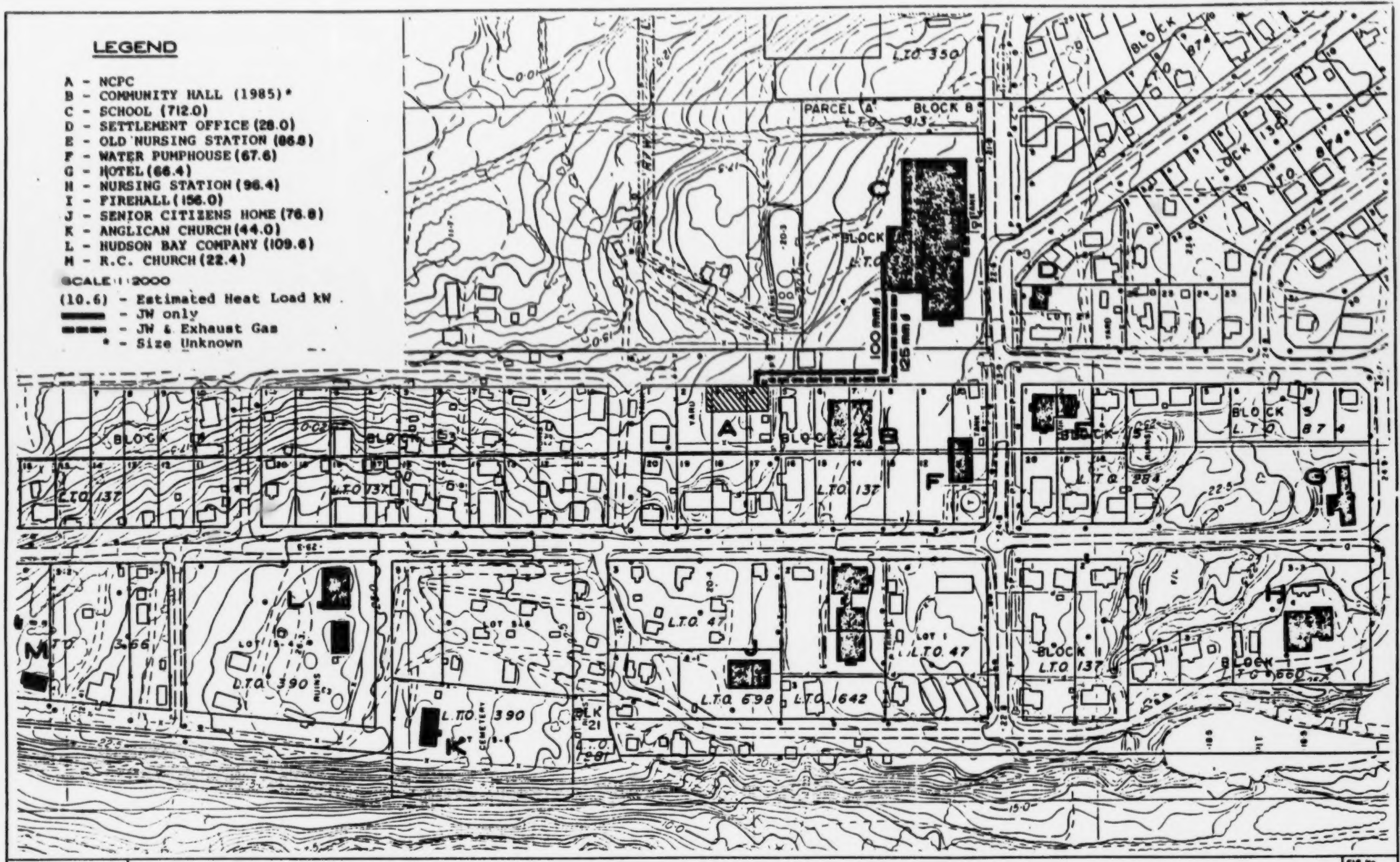
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ - JW & Exhaust Gas

LOT 95
LTO 1186
LOT 1
LOT 2
LOT 3
BLOCK
1186
LOT 11-4
LTO 1053
LOT 11-4(REM)
LTO 1058
LTO
1086
11-6(REM)
LOT 11-8
LOT 11-5
LOT 11-9
1053
LTO 1507
LOT 4 BLK 1
1248
11-(REM)
LOT
73mm Ø
50mm Ø

DILLON

FORT LIARD

D15


A
B
C
D
E
F
G
H
J
K
L
M
PARCEL A
BLOCK 8
L.T.O. 913
L.T.O. 350
BLOCK
L.T.O. 137
L.T.O. 284
BLOCK 5
L.T.O. 874
L.T.O. 47
L.T.O. 698
L.T.O. 642
L.T.O. 390
L.T.O. 366
BLK 21
CEMETERY
RUINS
LOT 1
100 mm ⌀
125 mm ⌀

LEGEND

A - NCPC
B - COMMUNITY HALL (1985)*
C - SCHOOL (712.0)
D - SETTLEMENT OFFICE (28.0)
E - OLD NURSING STATION (86.8)
F - WATER PUMPHOUSE (67.6)
G - HOTEL (66.4)
H - NURSING STATION (96.4)
I - FIREHALL (156.0)
J - SENIOR CITIZENS HOME (76.8)
K - ANGLICAN CHURCH (44.0)
L - HUDSON BAY COMPANY (109.6)
M - R.C. CHURCH (22.4)

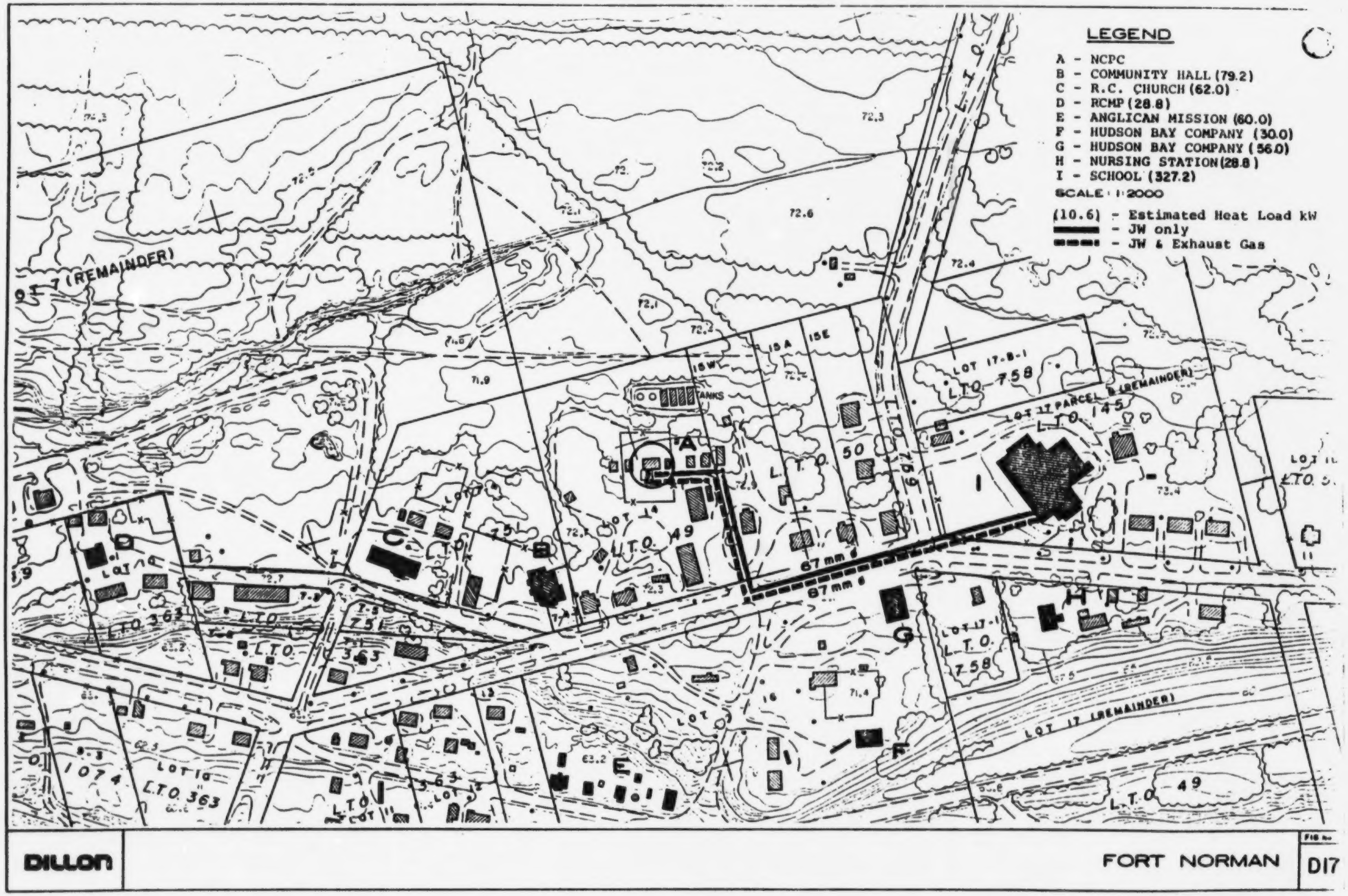
SCALE 1:2000

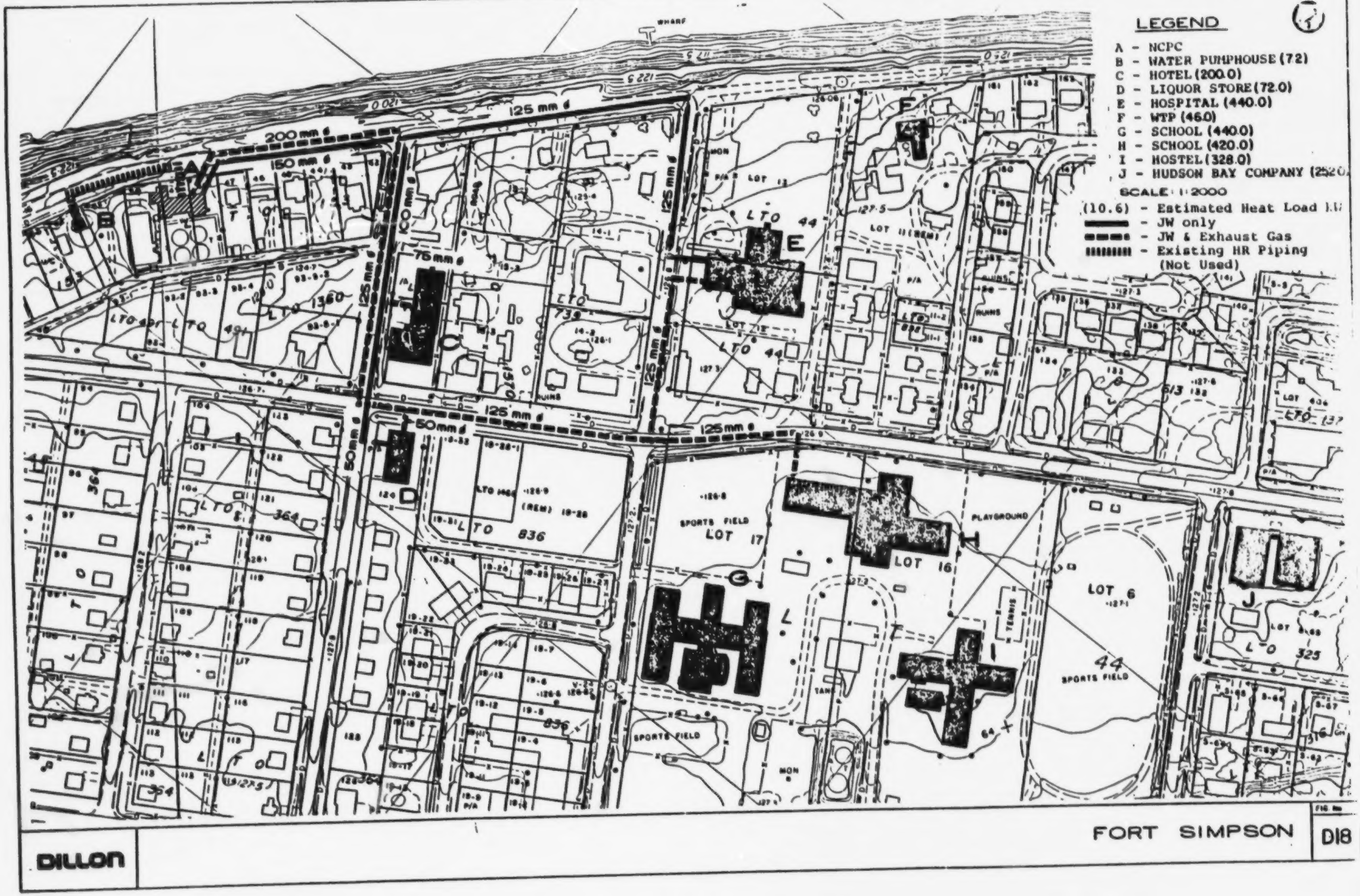
(10.6) - Estimated Heat Load kW
▬▬ - JW only
▬ ▬ - JW & Exhaust Gas
* - Size Unknown

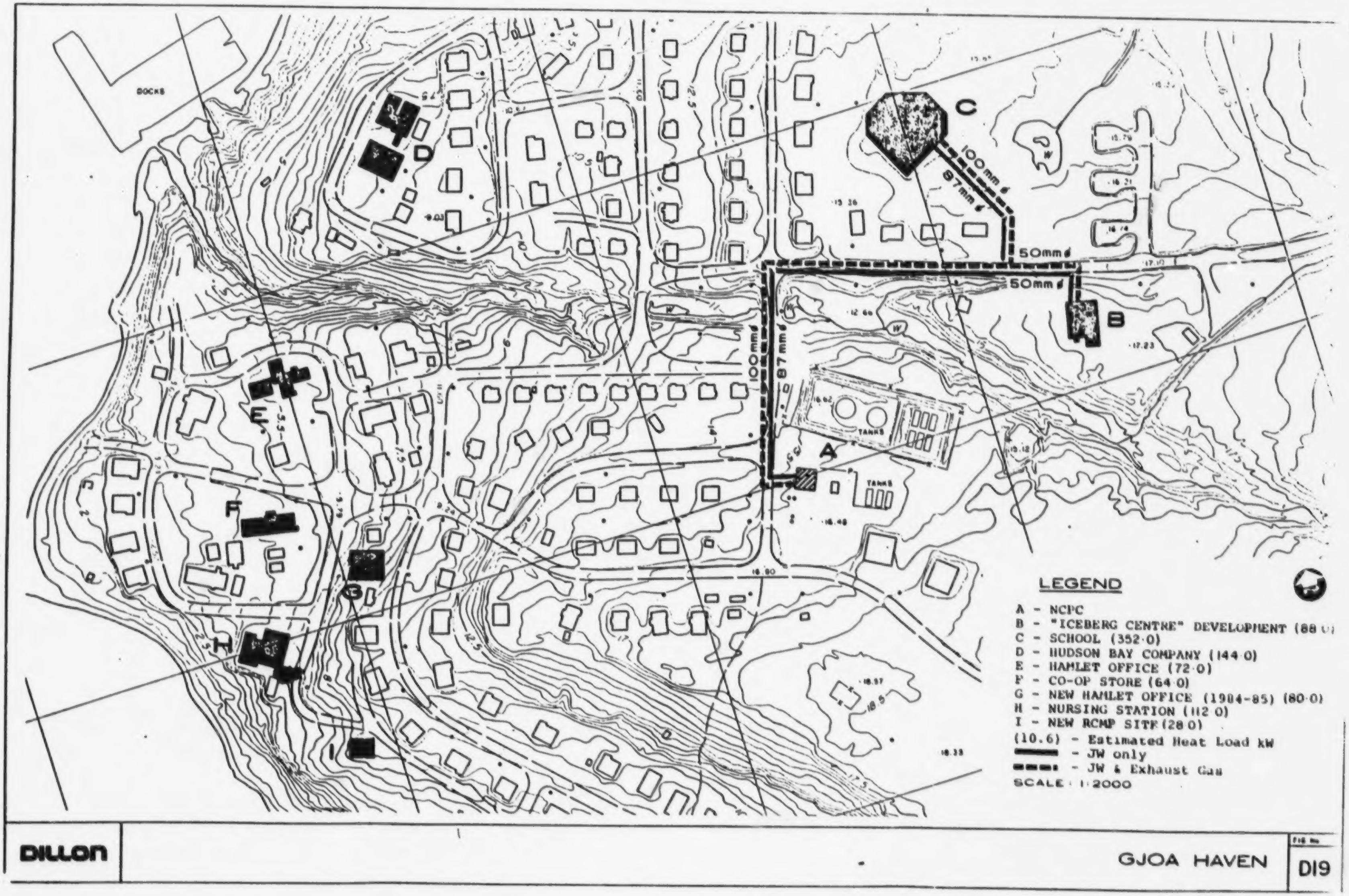
DILLON

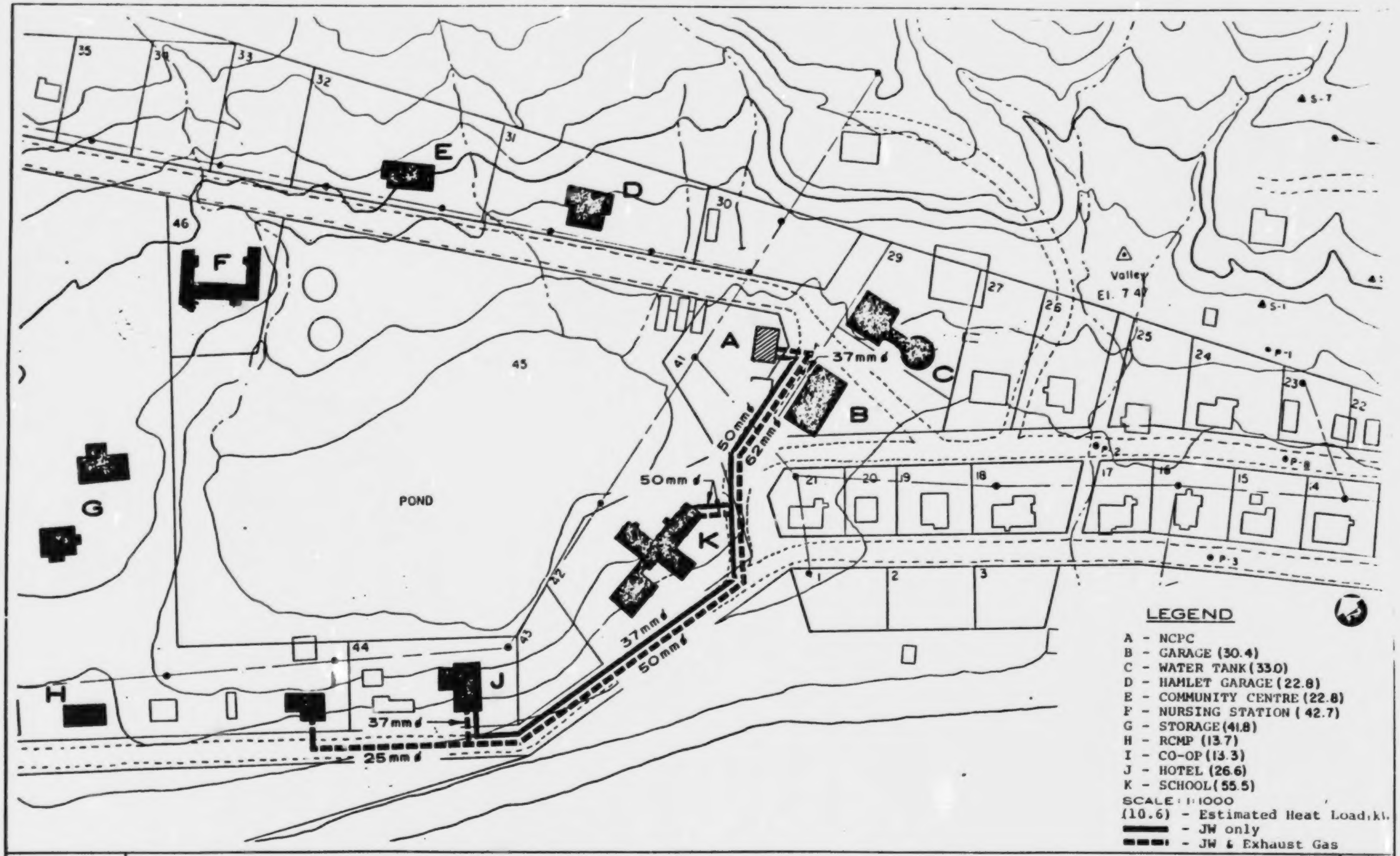
FORT McPHERSON

FIG No
D16


LEGEND
A - NCPC
B - COMMUNITY HALL (79.2)
C - R.C. CHURCH (62.0)
D - RCMP (28.8)
E - ANGLICAN MISSION (60.0)
F - HUDSON BAY COMPANY (30.0)
G - HUDSON BAY COMPANY (56.0)
H - NURSING STATION (28.8)
I - SCHOOL (327.2)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
TANKS
67 mm ø
LOT 7 (REMAINDER)
LOT 17-B-1
L.T.O. 758
LOT 17 PARCEL B (REMAINDER)
L.T.O. 145
L.T.O. 50
L.T.O. 759
L.T.O. 49
LOT 17 (REMAINDER)
L.T.O. 751
L.T.O. 363
1074
DILLON
FORT NORMAN
D17


LEGEND
A - NCPC
B - WATER PUMPHOUSE (72)
C - HOTEL (200.0)
D - LIQUOR STORE (72.0)
E - HOSPITAL (440.0)
F - WTP (46.0)
G - SCHOOL (440.0)
H - SCHOOL (420.0)
I - HOSTEL (328.0)
J - HUDSON BAY COMPANY (252.0
SCALE 1:2000
(10.6) - Estimated Heat Load
- JW only
- JW & Exhaust Gas
- Existing HR Piping (Not Used)
WHARF
200 mm ø
150 mm ø
125 mm ø
100 mm ø
75 mm ø
50 mm ø
SPORTS FIELD
LOT 17
LOT 16
LOT 6
PLAYGROUND
TENNIS
FORT SIMPSON
DILLON
D18


DOCKS
C
100mm ø
87mm ø
50mm ø
50mm ø
B
100mm ø
87mm ø
TANKS
TANKS
A
D
E
F
G
H
I
LEGEND
A - NCPC
B - "ICEBERG CENTRE" DEVELOPMENT (88·0)
C - SCHOOL (352·0)
D - HUDSON BAY COMPANY (144·0)
E - HAMLET OFFICE (72·0)
F - CO-OP STORE (64·0)
G - NEW HAMLET OFFICE (1984-85) (80·0)
H - NURSING STATION (112·0)
I - NEW RCMP SITE (28·0)
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
SCALE : 1:2000
DILLON
GJOA HAVEN
Fig No
D19


35
34
33
32
31
30
29
27
26
25
24
23
22
46
45
41
42
43
44
21
20
19
18
17
16
15
4
1
2
3
E
D
F
A
B
C
G
K
J
H
POND
Valley
El. 7 4?
S-7
S-1
P-1
P-2
P-8
P-3
37mm ø
50mm ø
62mm ø
50mm ø
37mm ø
50mm ø
37mm ø
25mm ø
LEGEND
A - NCPC
B - GARAGE (30.4)
C - WATER TANK (33.0)
D - HAMLET GARAGE (22.8)
E - COMMUNITY CENTRE (22.8)
F - NURSING STATION (42.7)
G - STORAGE (41.8)
H - RCMP (13.7)
I - CO-OP (13.3)
J - HOTEL (26.6)
K - SCHOOL (55.5)
SCALE 1:1000
(10.6) - Estimated Heat Load, kW
- JW only
- JW & Exhaust Gas

DILLON

GRISE FIORD

FIG No D20

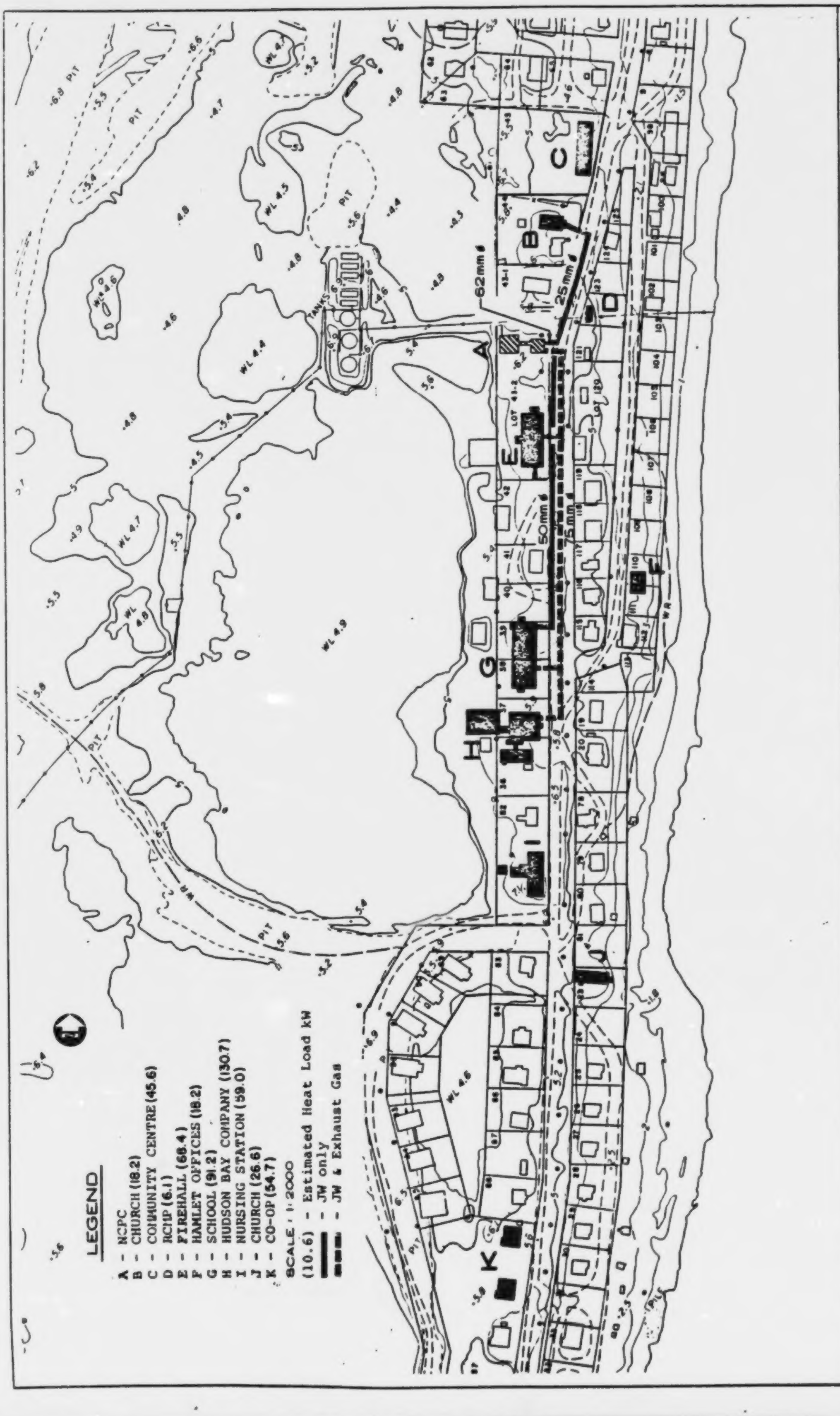
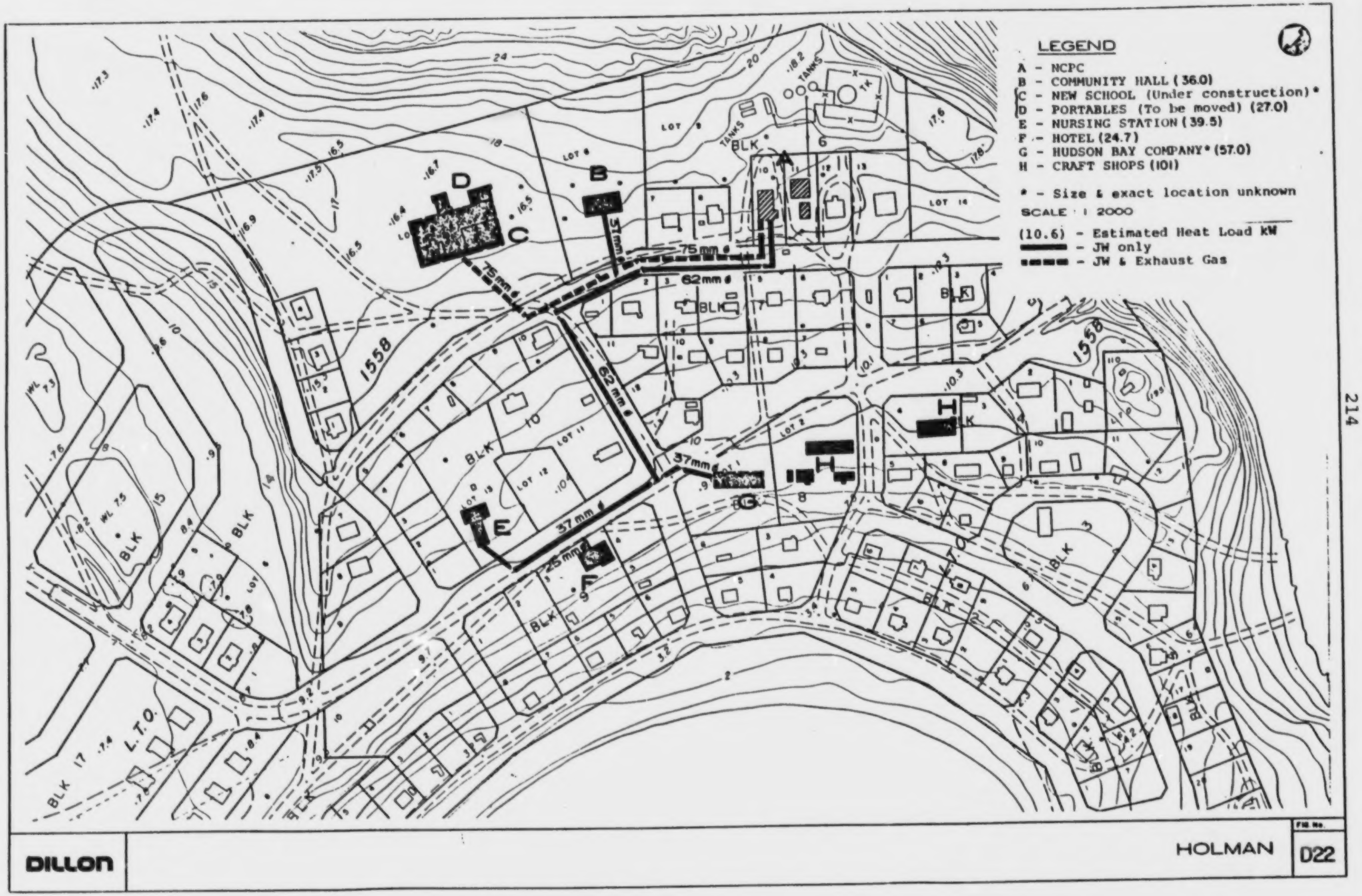
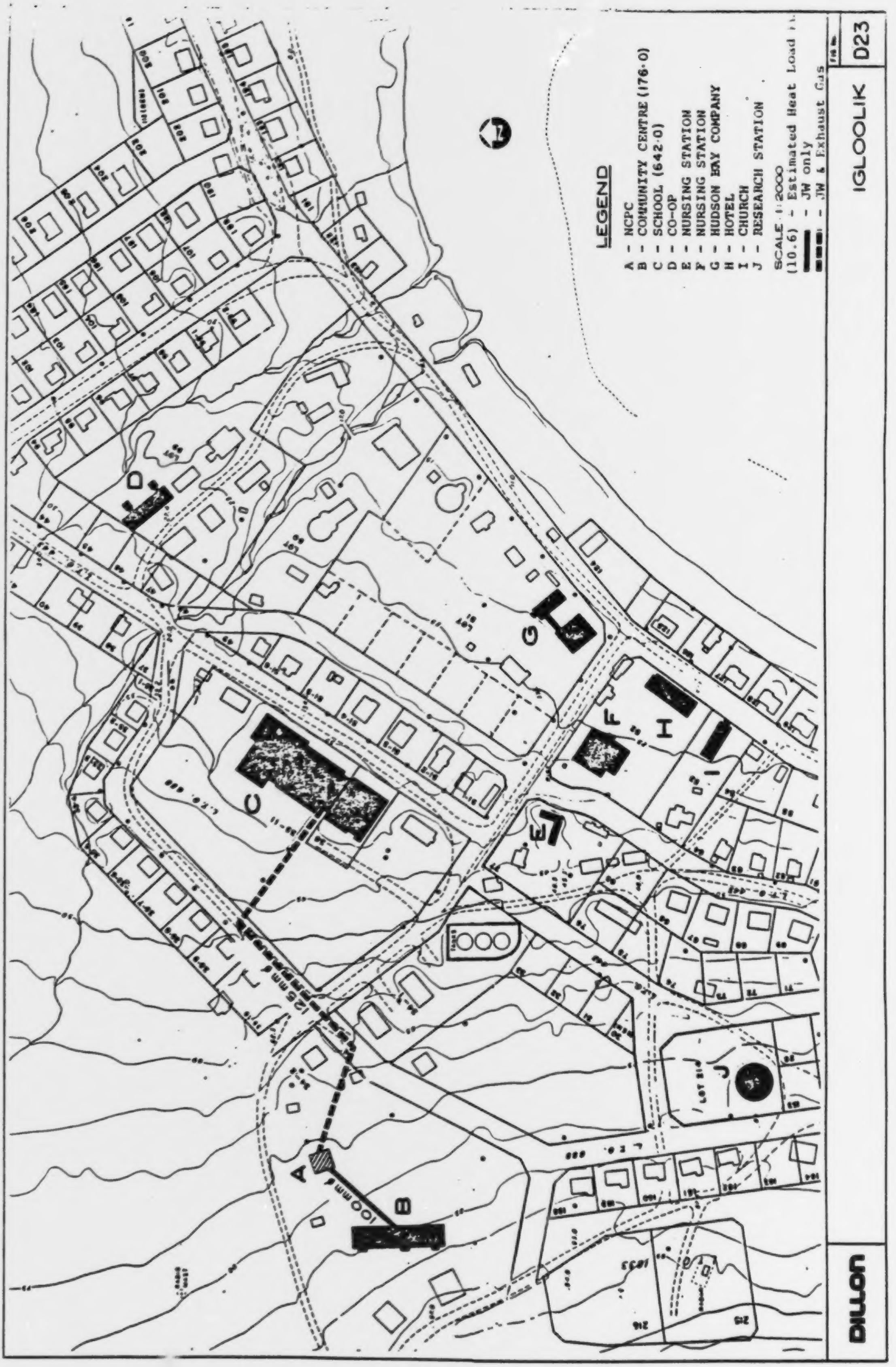

LEGEND
A - NCPC
B - CHURCH (18.2)
C - COMMUNITY CENTRE (45.6)
D - RCMP (6.1)
E - FIREHALL (68.4)
F - HAMLET OFFICES (18.2)
G - SCHOOL (91.2)
H - HUDSON BAY COMPANY (130.7)
I - NURSING STATION (59.0)
J - CHURCH (26.6)
K - CO-OP (54.7)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ - JW & Exhaust Gas
62mm ø
25mm ø
50mm ø
75mm ø
TANKS
PIT
WL 4.9
WL 4.4
WL 4.5
WL 4.7
WL 4.6
WR

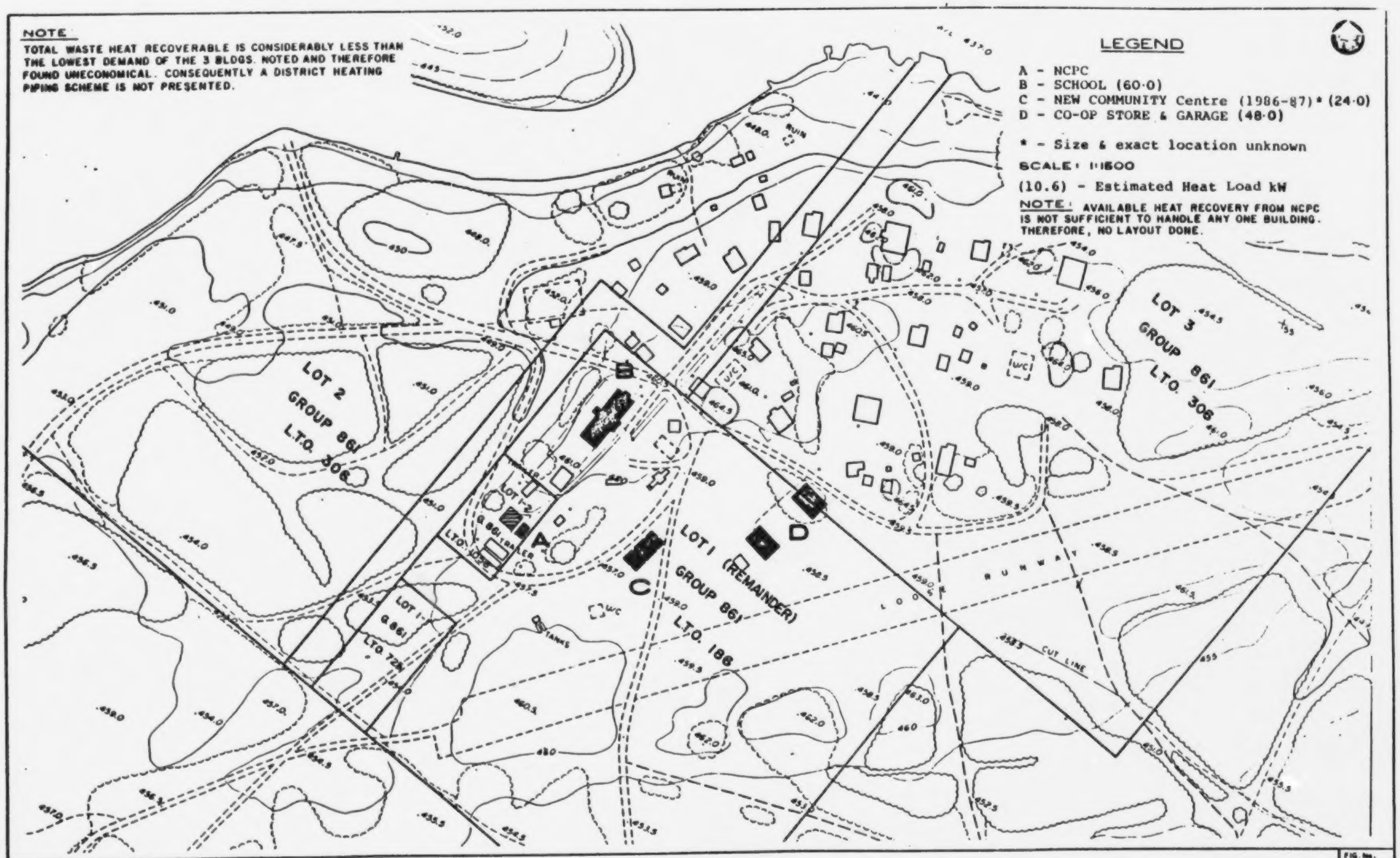
FIG No. D21

HALL BEACH

Dillon


LEGEND
A - NCPC
B - COMMUNITY HALL (36.0)
C - NEW SCHOOL (Under construction)*
D - PORTABLES (To be moved) (27.0)
E - NURSING STATION (39.5)
F - HOTEL (24.7)
G - HUDSON BAY COMPANY* (57.0)
H - CRAFT SHOPS (101)
* - Size & exact location unknown
SCALE 1 : 2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
75 mm ø
62 mm ø
37 mm ø
25 mm ø
1558
BLK
LOT
TANKS
L.T.O.
DILLON
HOLMAN
FIG No.
D22


LEGEND
A - NCPC
B - COMMUNITY CENTRE (176·0)
C - SCHOOL (642·0)
D - CO-OP
E - NURSING STATION
F - NURSING STATION
G - HUDSON BAY COMPANY
H - HOTEL
I - CHURCH
J - RESEARCH STATION
SCALE 1:2000
(10.6) - Estimated Heat Load
- JW only
- JW & Exhaust Gas
IGLOOLIK
D23
DILLON
A
B
C
D
E
F
G
H
I
J
100mm
125mm


LOT 2
GROUP 861
L.T.O. 306
LOT 3
GROUP 861
L.T.O. 306
LOT 1 (REMAINDER)
GROUP 861
L.T.O. 188
LOT 1-2
G 861
L.T.O. 1026
LOT 1-1
G 861
L.T.O. 726
A
B
C
D
RUNWAY
CUT LINE
RUIN
TANKS
U/C

NOTE:
TOTAL WASTE HEAT RECOVERABLE IS CONSIDERABLY LESS THAN THE LOWEST DEMAND OF THE 3 BLDGS. NOTED AND THEREFORE FOUND UNECONOMICAL. CONSEQUENTLY A DISTRICT HEATING PIPING SCHEME IS NOT PRESENTED.

LEGEND

A - NCPC
B - SCHOOL (60·0)
C - NEW COMMUNITY Centre (1986-87)* (24·0)
D - CO-OP STORE & GARAGE (48·0)

* - Size & exact location unknown

SCALE: 1:1500

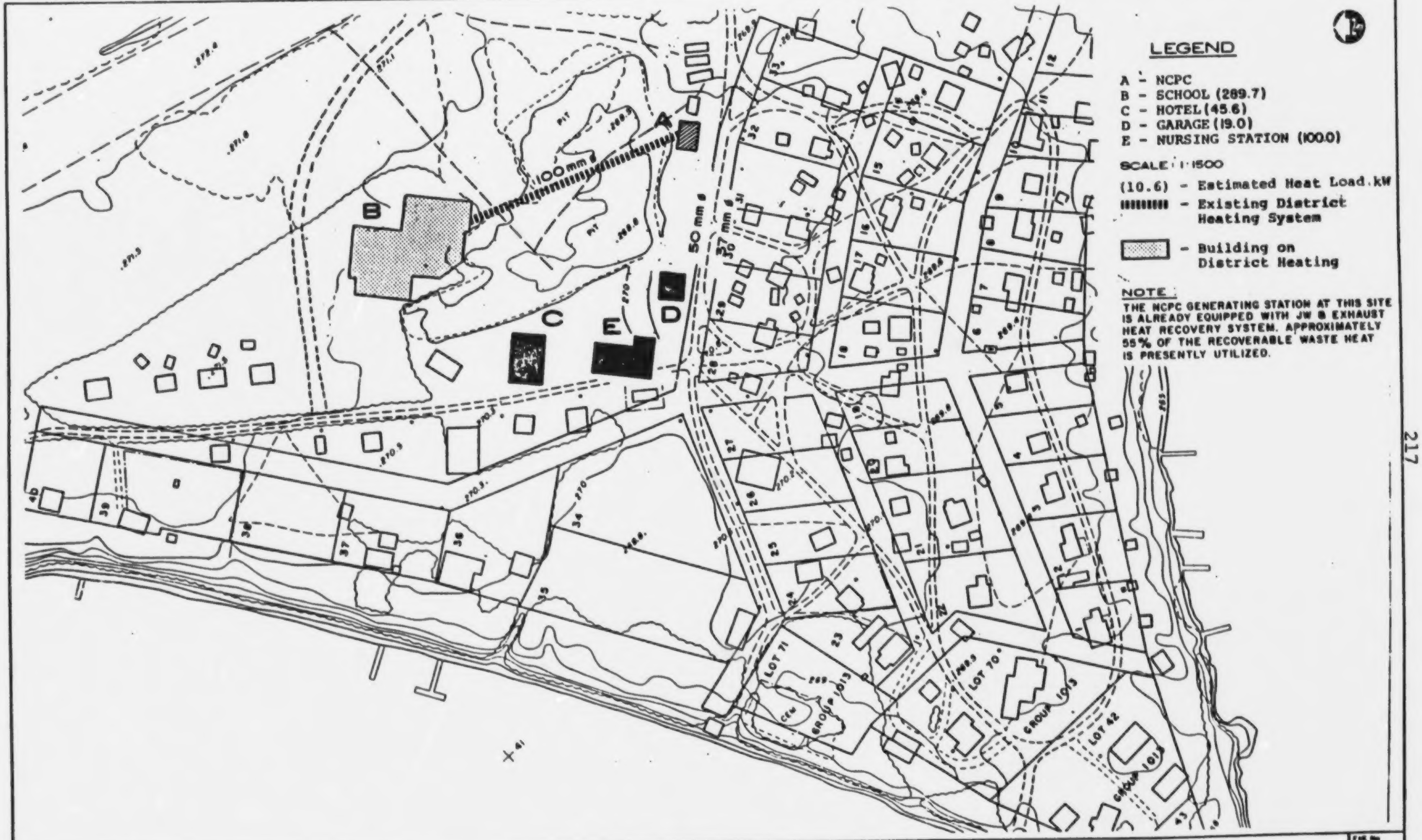
(10.6) - Estimated Heat Load kW

NOTE: AVAILABLE HEAT RECOVERY FROM NCPC IS NOT SUFFICIENT TO HANDLE ANY ONE BUILDING. THEREFORE, NO LAYOUT DONE.

DILLON

JEAN MARIE RIVER

FIG. No.
D24


A
B
C
D
E
100 mm ø
50 mm ø
37 mm ø
LOT 71
LOT 70
LOT 42
GROUP 1013

LEGEND

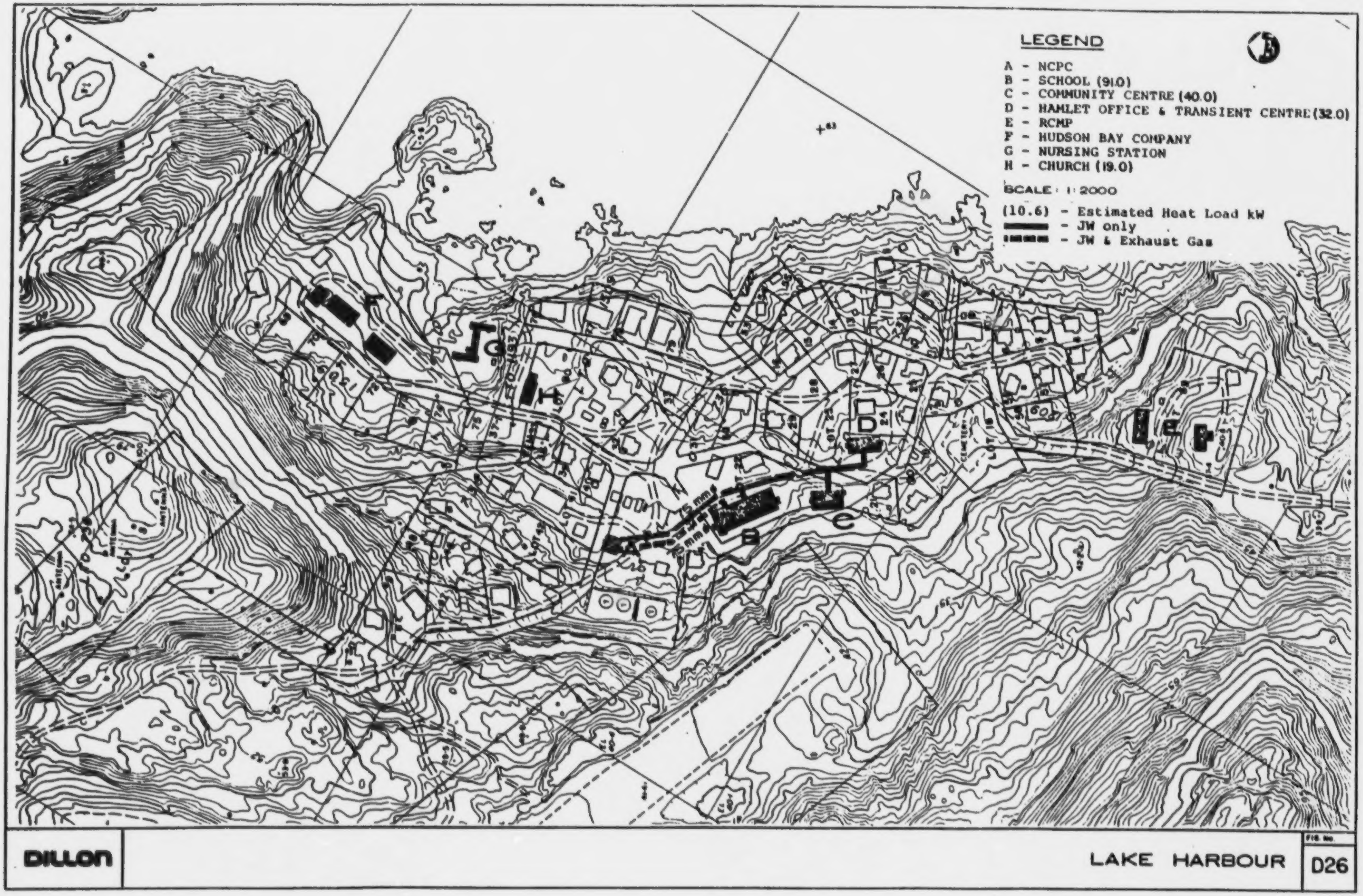
A - NCPC
B - SCHOOL (289.7)
C - HOTEL (45.6)
D - GARAGE (19.0)
E - NURSING STATION (100.0)

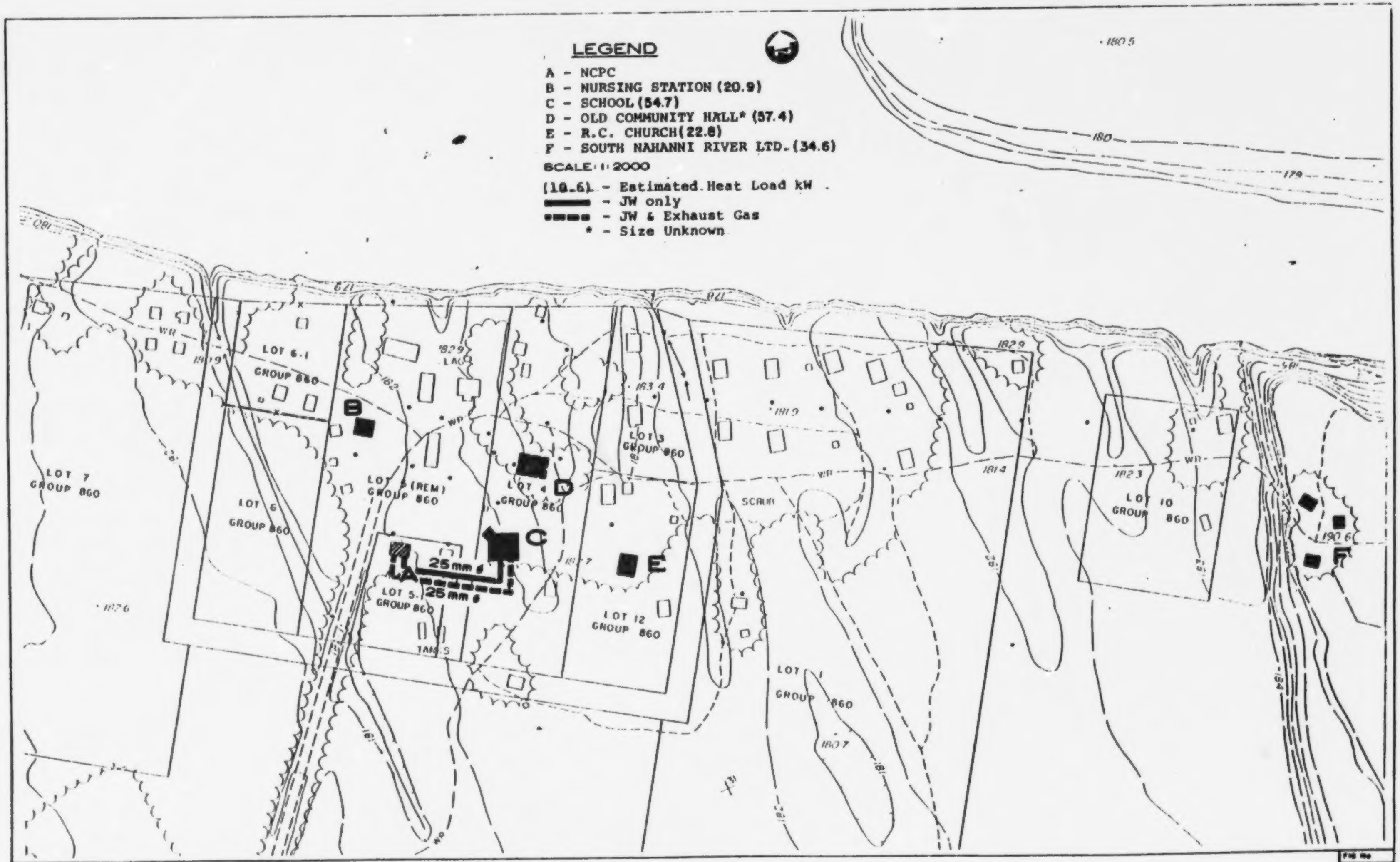
SCALE 1:1500

(10.6) - Estimated Heat Load.kW
▮▮▮▮ - Existing District Heating System
▨ - Building on District Heating

NOTE :
THE NCPC GENERATING STATION AT THIS SITE IS ALREADY EQUIPPED WITH JW & EXHAUST HEAT RECOVERY SYSTEM. APPROXIMATELY 55% OF THE RECOVERABLE WASTE HEAT IS PRESENTLY UTILIZED.

DILLON	LAC LA MARTRE	FIG No D25

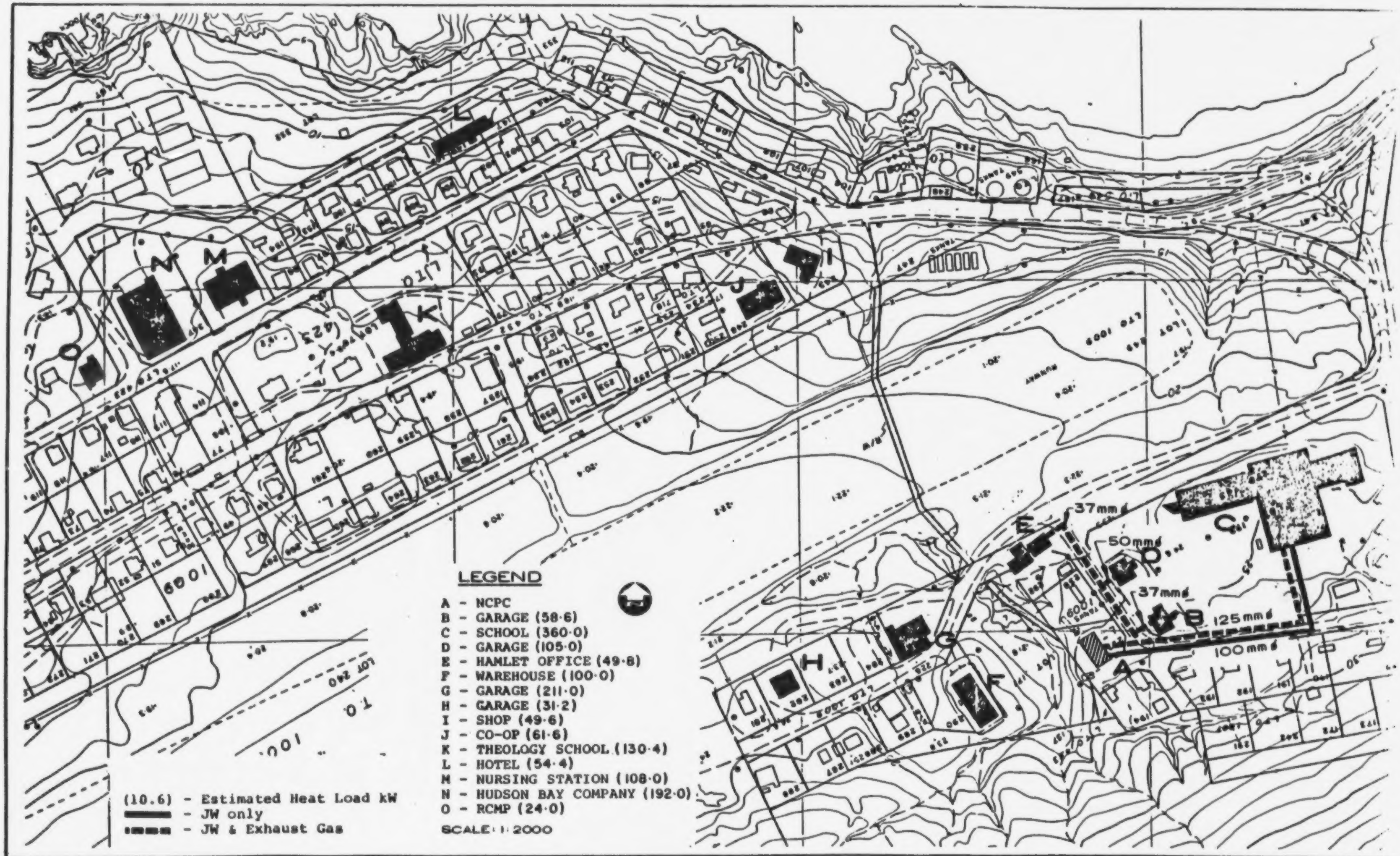

LEGEND
A - NCPC
B - SCHOOL (91.0)
C - COMMUNITY CENTRE (40.0)
D - HAMLET OFFICE & TRANSIENT CENTRE (32.0)
E - RCMP
F - HUDSON BAY COMPANY
G - NURSING STATION
H - CHURCH (19.0)
SCALE: 1:2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
A
B
C
D
E
F
G
H
DILLON
LAKE HARBOUR
FIG. No.
D26


LEGEND
A - NCPC
B - NURSING STATION (20.9)
C - SCHOOL (54.7)
D - OLD COMMUNITY HALL* (57.4)
E - R.C. CHURCH (22.8)
F - SOUTH NAHANNI RIVER LTD. (34.6)
SCALE 1:2000
(18.6) - Estimated Heat Load kW
▬ - JW only
▬▬▬ - JW & Exhaust Gas
* - Size Unknown
A
B
C
D
E
F
25mm ø
25mm ø
LOT 7 GROUP 860
LOT 6-1 GROUP 860
LOT 6 GROUP 860
LOT 5 (REM) GROUP 860
LOT 5-1 GROUP 860
LOT 4 GROUP 860
LOT 3 GROUP 860
LOT 12 GROUP 860
LOT 1 GROUP 860
LOT 10 GROUP 860
TANKS
SCRUB
WR
180.5
180
179
180
181
182
182.9
181.9
183.4
182.7
181.9
182.9
181.4
182.3
180.7
181
184
190.6
182.6

DILLON

NAHANNI BUTTE

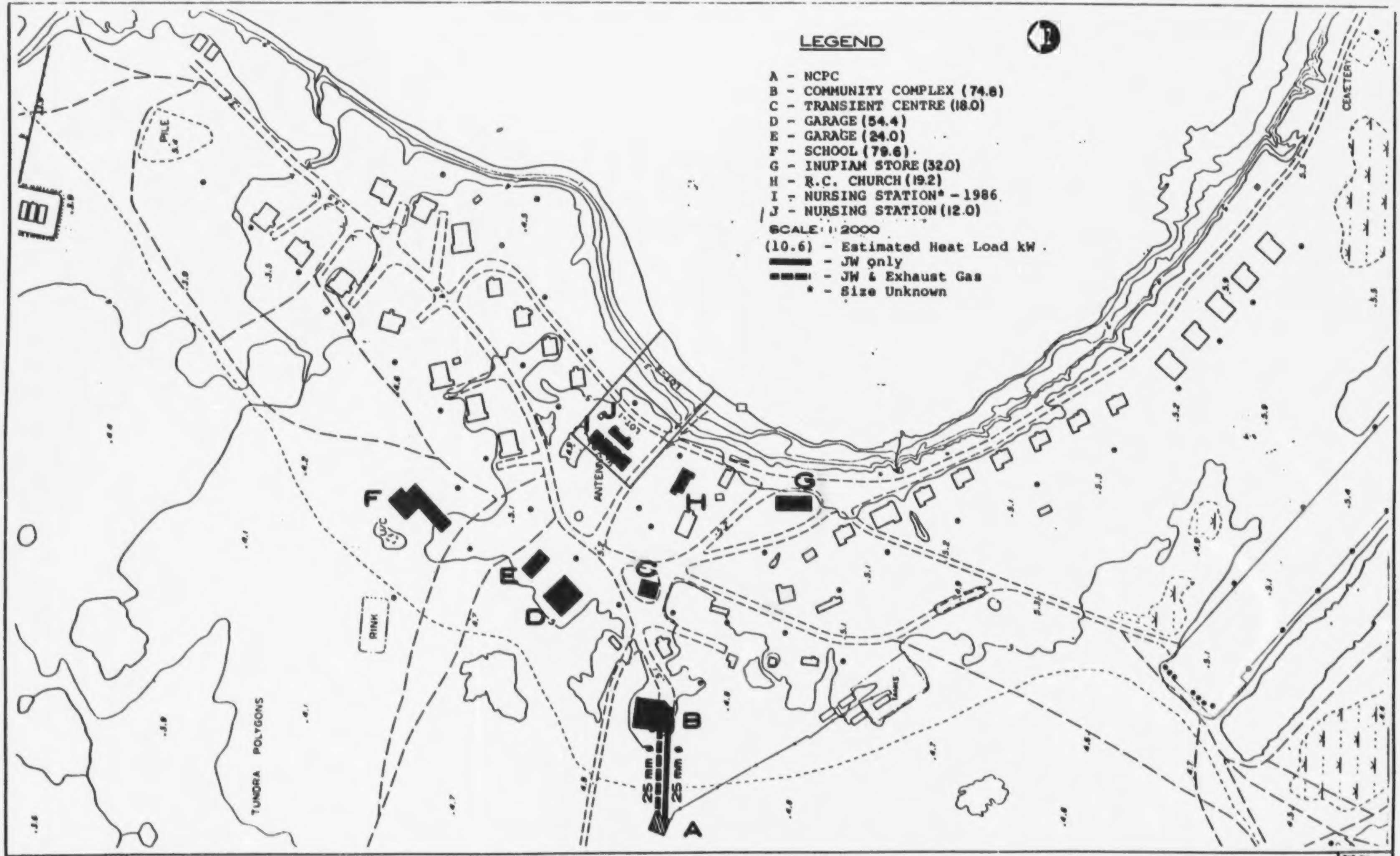
Fig No D27


LEGEND
A - NCPC
B - GARAGE (58·6)
C - SCHOOL (360·0)
D - GARAGE (105·0)
E - HAMLET OFFICE (49·8)
F - WAREHOUSE (100·0)
G - GARAGE (211·0)
H - GARAGE (31·2)
I - SHOP (49·6)
J - CO-OP (61·6)
K - THEOLOGY SCHOOL (130·4)
L - HOTEL (54·4)
M - NURSING STATION (108·0)
N - HUDSON BAY COMPANY (192·0)
O - RCMP (24·0)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
37mmø
50mmø
37mmø
125mmø
100mmø
T.O.
LOT 240
LOT 1009

DILLON

PANGNIRTUNG

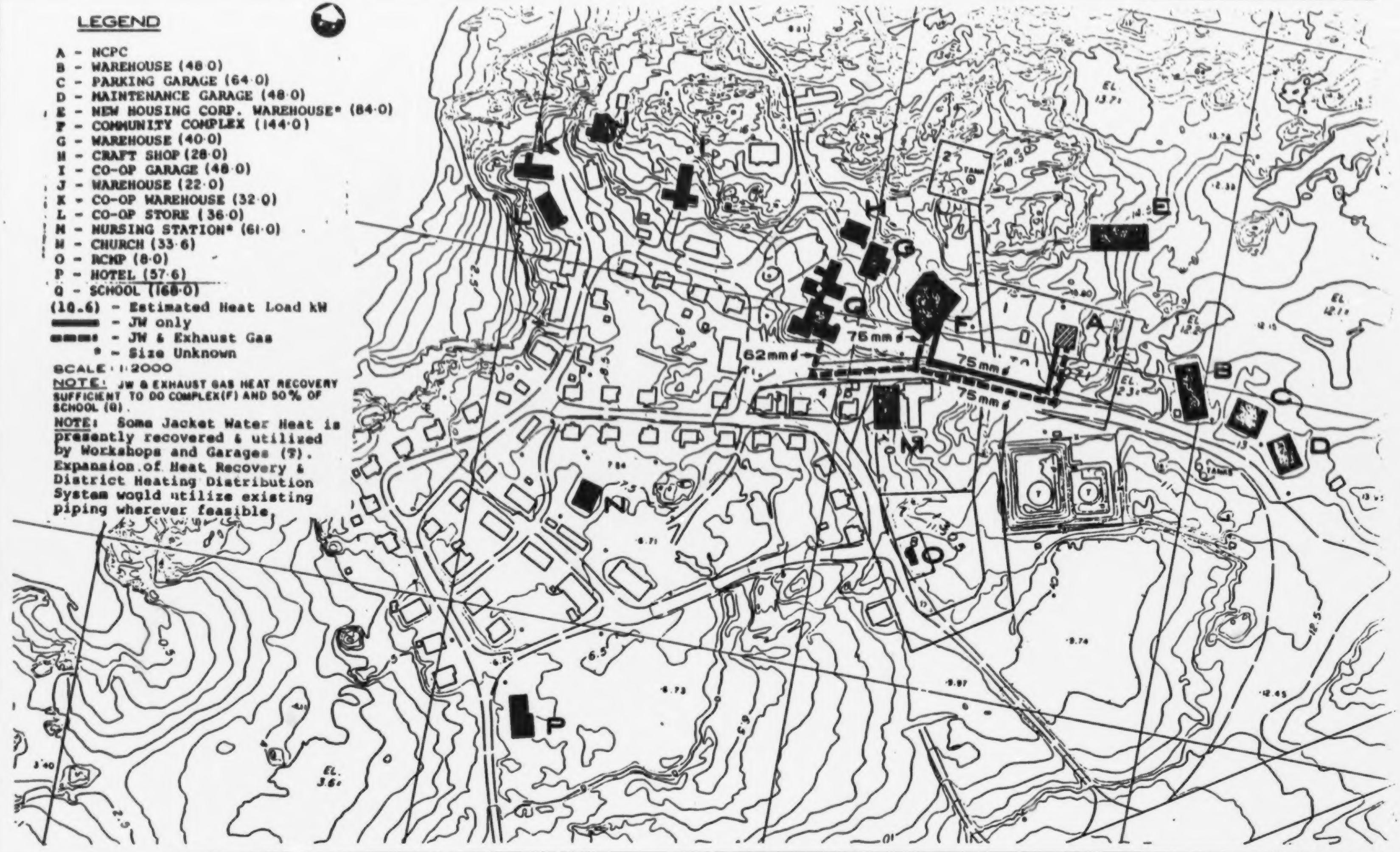
FIG No D28


LEGEND
A - NCPC
B - COMMUNITY COMPLEX (74.8)
C - TRANSIENT CENTRE (18.0)
D - GARAGE (54.4)
E - GARAGE (24.0)
F - SCHOOL (79.6)
G - INUPIAM STORE (32.0)
H - R.C. CHURCH (19.2)
I - NURSING STATION* - 1986
J - NURSING STATION (12.0)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
* - Size Unknown
CEMETERY
PILE
RINK
TUNDRA POLYGONS
ANTENNA
25 mm
25 mm
A
B
C
D
E
F
G
H
I
J

DILLON

PAULATUK

FIG. No. D29


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
75mmø
75mmø
75mmø
75mmø
62mmø
EL. 13.71
EL. 12.1
EL. 12.2
EL. 3.6
2.5
6.5
TANK

LEGEND

A - NCPC
B - WAREHOUSE (48·0)
C - PARKING GARAGE (64·0)
D - MAINTENANCE GARAGE (48·0)
E - NEW HOUSING CORP. WAREHOUSE* (84·0)
F - COMMUNITY COMPLEX (144·0)
G - WAREHOUSE (40·0)
H - CRAFT SHOP (28·0)
I - CO-OP GARAGE (48·0)
J - WAREHOUSE (22·0)
K - CO-OP WAREHOUSE (32·0)
L - CO-OP STORE (36·0)
M - NURSING STATION* (61·0)
N - CHURCH (33·6)
O - RCMP (8·0)
P - HOTEL (57·6)
Q - SCHOOL (168·0)
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
* - Size Unknown

SCALE 1:2000

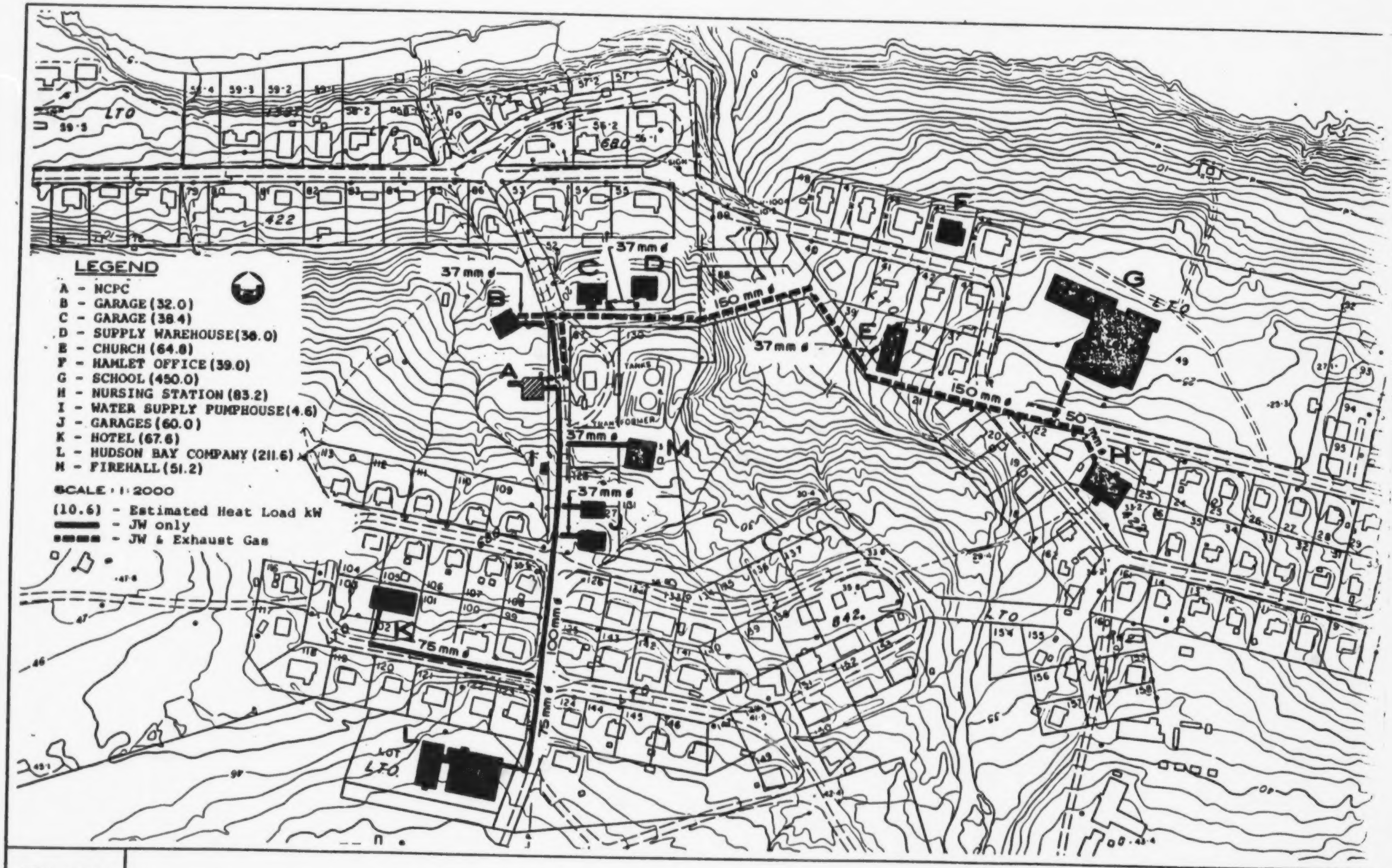
NOTE: JW & EXHAUST GAS HEAT RECOVERY SUFFICIENT TO DO COMPLEX(F) AND 50% OF SCHOOL (Q).

NOTE: Some Jacket Water Heat is presently recovered & utilized by Workshops and Garages (F). Expansion of Heat Recovery & District Heating Distribution System would utilize existing piping wherever feasible.

DILLON

PELLY BAY

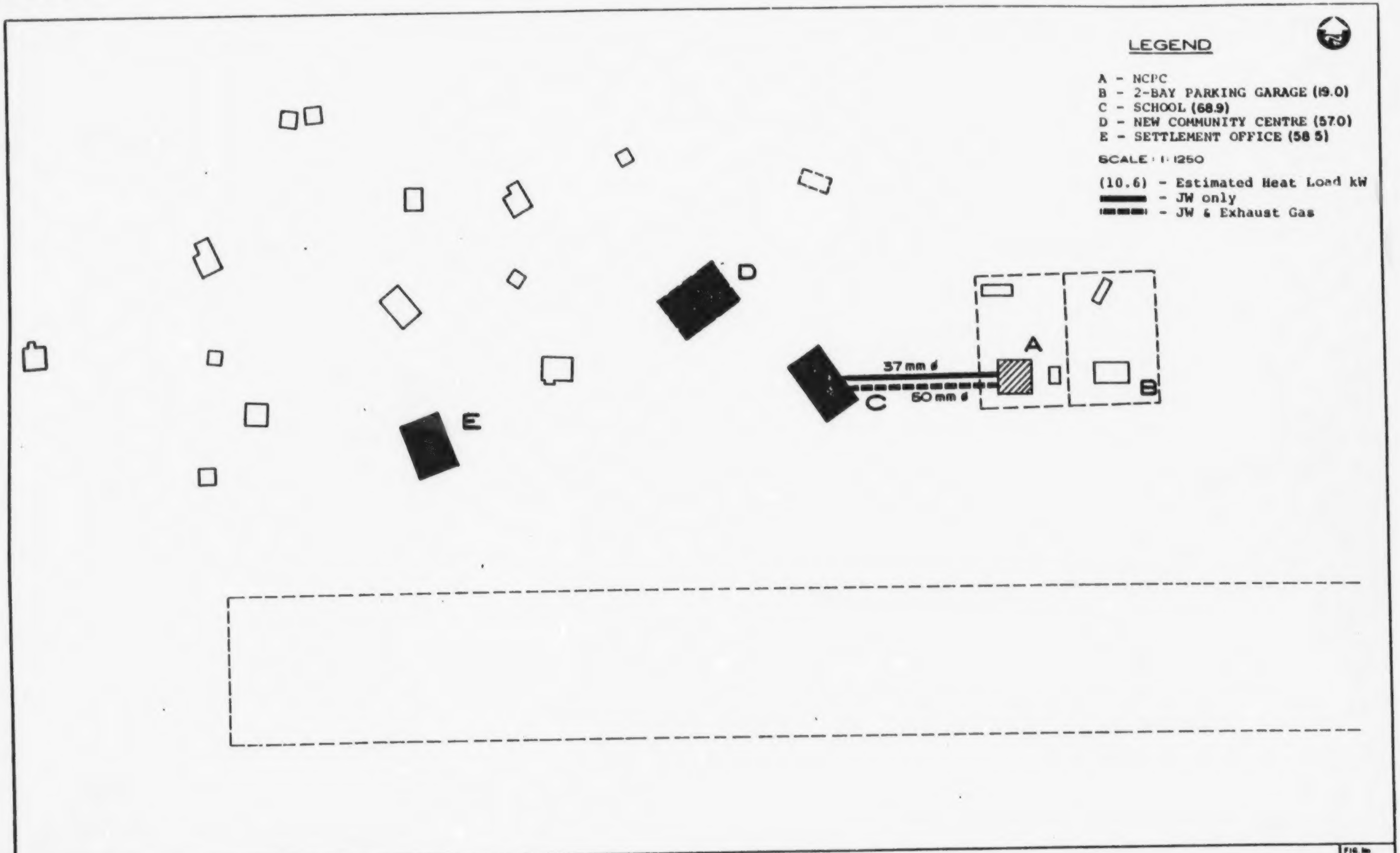
FIG No
D3


LEGEND
A - NCPC
B - GARAGE (32.0)
C - GARAGE (38.4)
D - SUPPLY WAREHOUSE (36.0)
E - CHURCH (64.8)
F - HAMLET OFFICE (39.0)
G - SCHOOL (450.0)
H - NURSING STATION (83.2)
I - WATER SUPPLY PUMPHOUSE (4.6)
J - GARAGES (60.0)
K - HOTEL (67.6)
L - HUDSON BAY COMPANY (211.6)
M - FIREHALL (51.2)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
37 mm ø
150 mm ø
50 mm
100 mm ø
75 mm ø
75 mm
TANKS
TRANSFORMER
LTO
LOT L.T.O.
422
680
842
A
B
C
D
E
F
G
H
I
J
K
L
M

DILLON

POND INLET

FIG. No D31

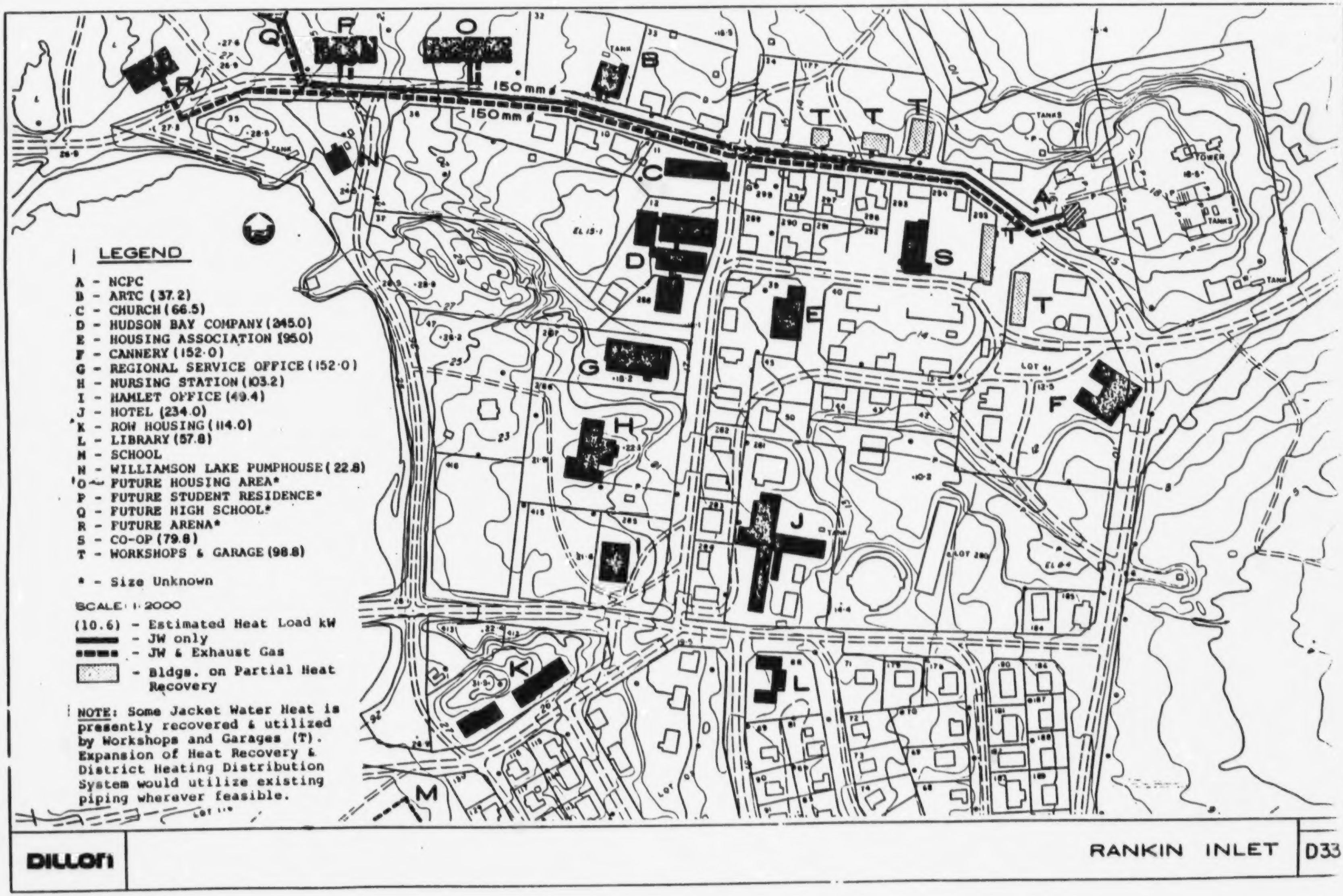

LEGEND
A - NCPC
B - 2-BAY PARKING GARAGE (19.0)
C - SCHOOL (68.9)
D - NEW COMMUNITY CENTRE (57.0)
E - SETTLEMENT OFFICE (58 5)
SCALE: 1:1250
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ - JW & Exhaust Gas
A
B
C
D
E
37 mm ø
50 mm ø

DILLON

RAE LAKES

FIG No

D32



A
B
C
D
E
F
G
H
J
K
L
M
N
O
P
Q
R
S
T
150mm ø
150mm ø
TANKS
TOWER
LOT 41
DILLON
RANKIN INLET
D33

LEGEND

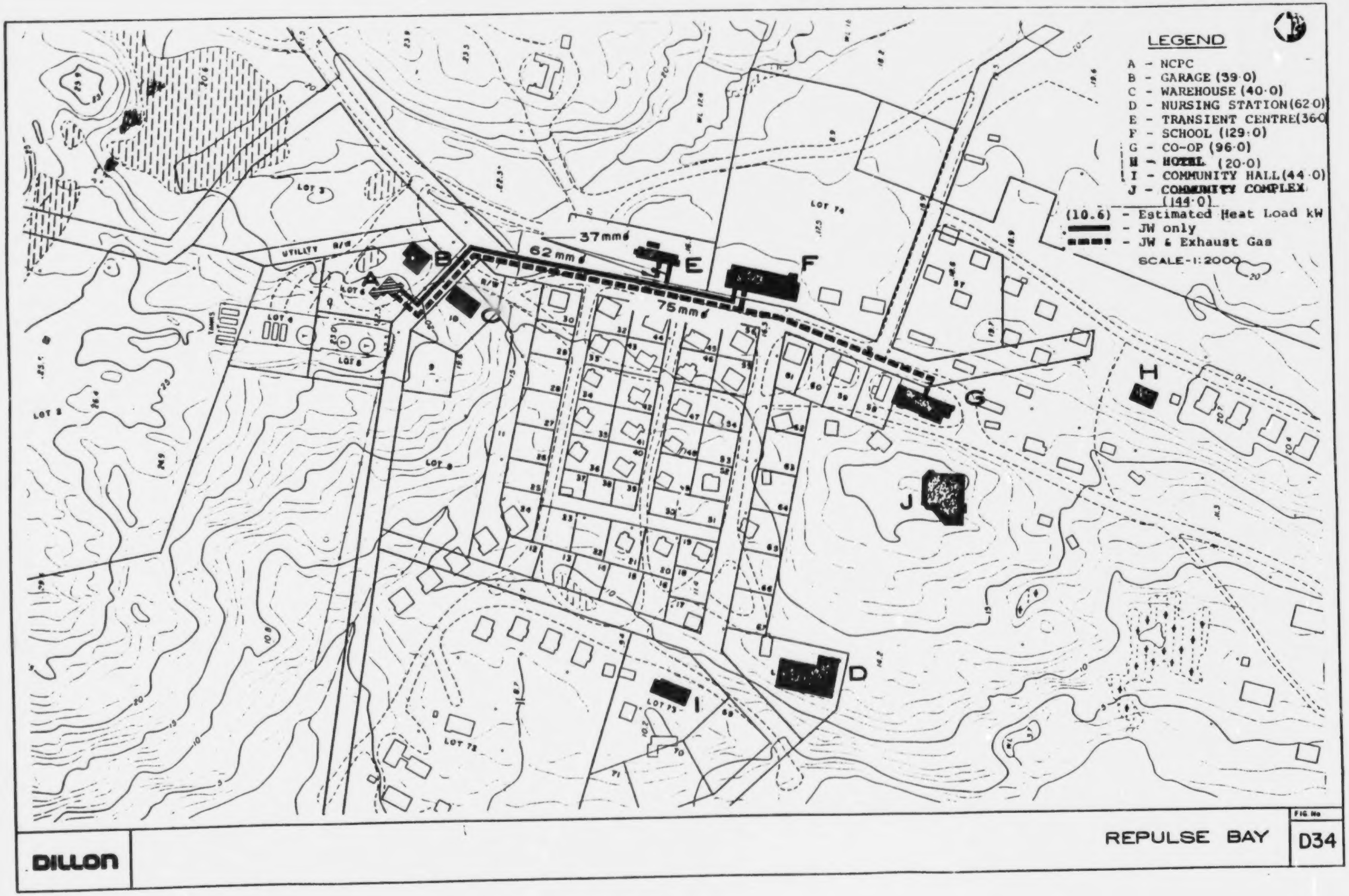
- A - NCPC
- B - ARTC (37.2)
- C - CHURCH (66.5)
- D - HUDSON BAY COMPANY (245.0)
- E - HOUSING ASSOCIATION (95.0)
- F - CANNERY (152·0)
- G - REGIONAL SERVICE OFFICE (152·0)
- H - NURSING STATION (103.2)
- I - HAMLET OFFICE (49.4)
- J - HOTEL (234.0)
- K - ROW HOUSING (114.0)
- L - LIBRARY (57.8)
- M - SCHOOL
- N - WILLIAMSON LAKE PUMPHOUSE (22.8)
- O - FUTURE HOUSING AREA*
- P - FUTURE STUDENT RESIDENCE*
- Q - FUTURE HIGH SCHOOL*
- R - FUTURE ARENA*
- S - CO-OP (79.8)
- T - WORKSHOPS & GARAGE (98.8)

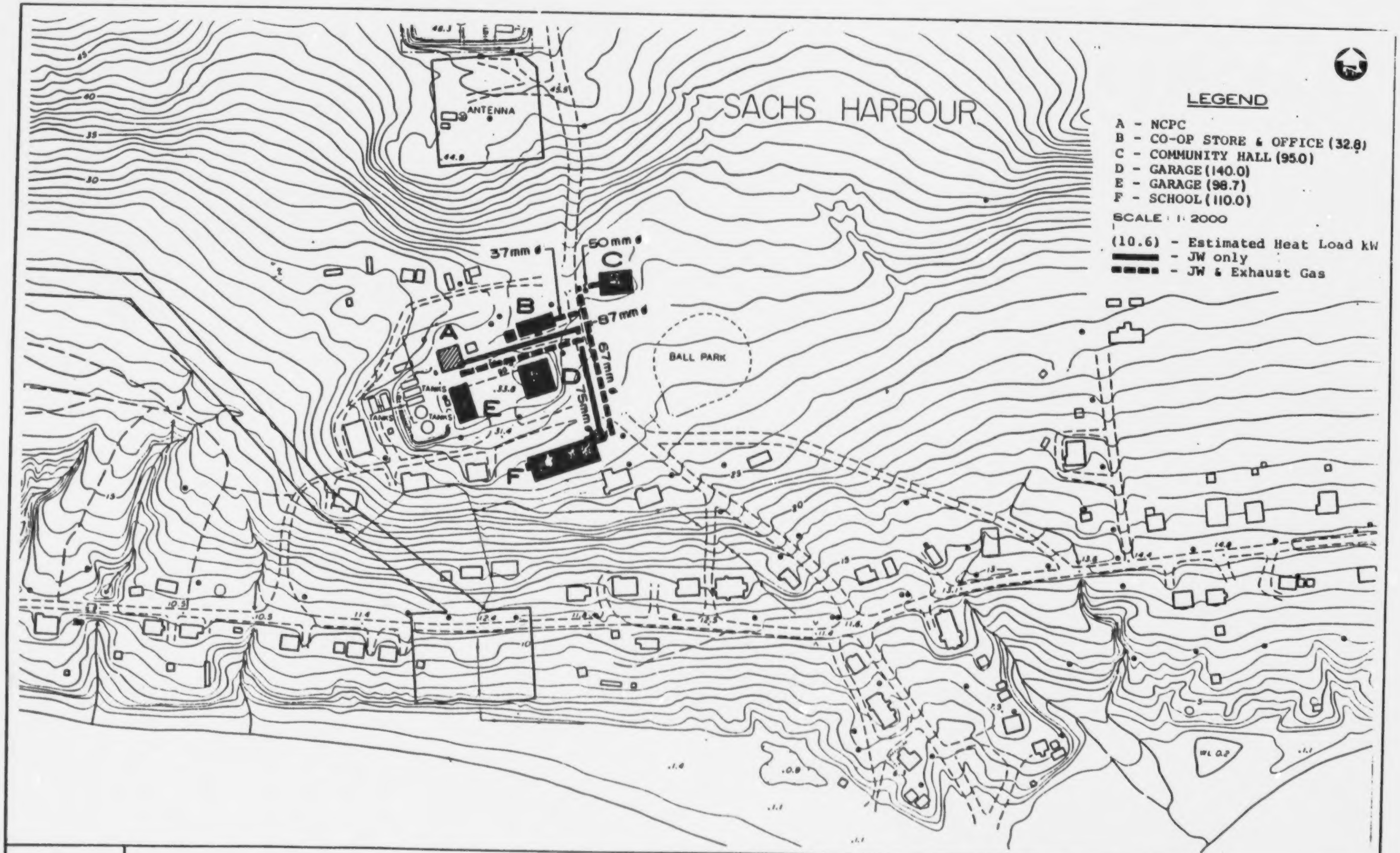
* - Size Unknown

SCALE 1:2000

(10.6) - Estimated Heat Load kW
━━━ - JW only
▬▬▬ - JW & Exhaust Gas
▨ - Bldgs. on Partial Heat Recovery

NOTE: Some Jacket Water Heat is presently recovered & utilized by Workshops and Garages (T). Expansion of Heat Recovery & District Heating Distribution System would utilize existing piping wherever feasible.

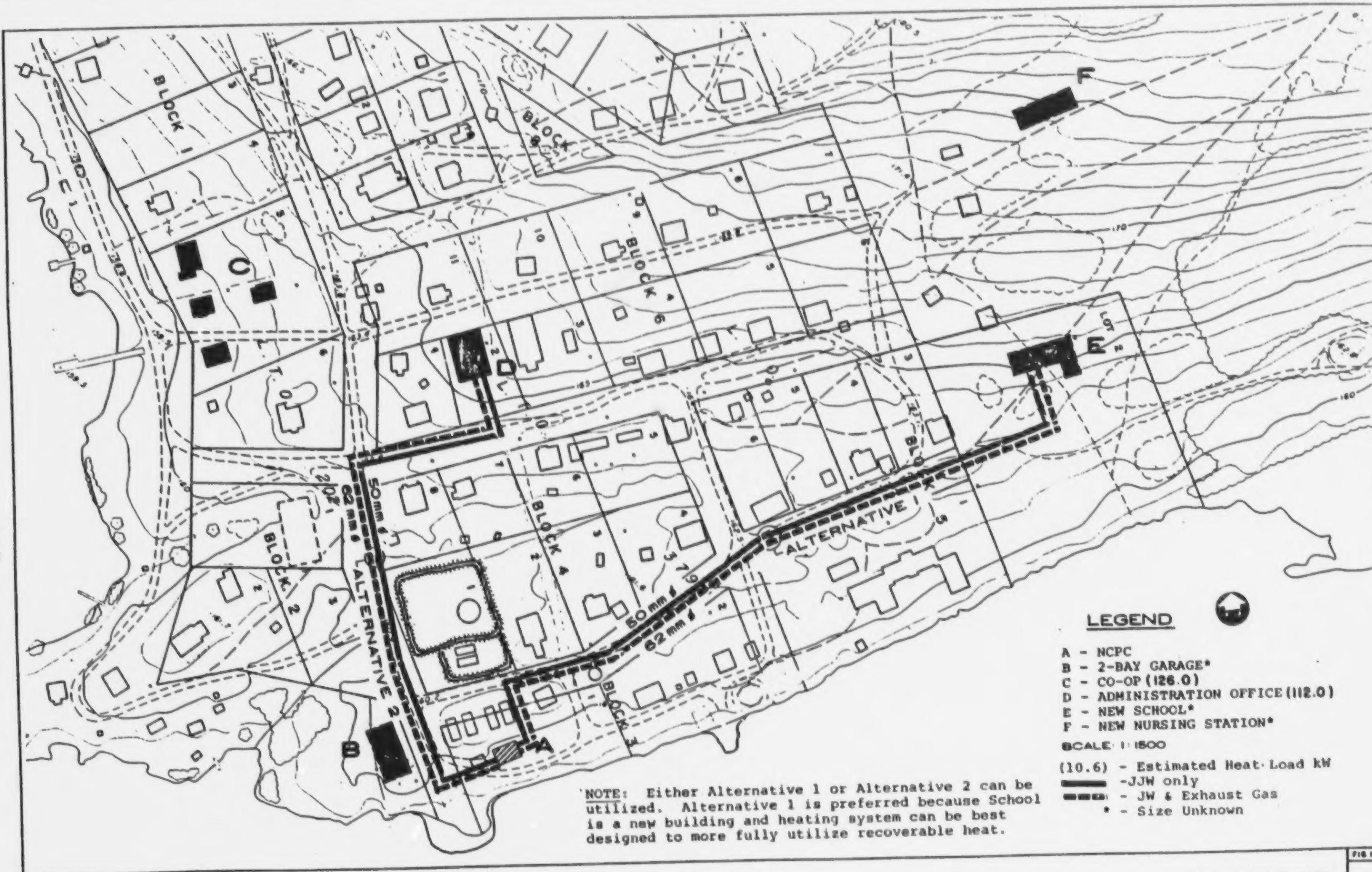

LEGEND
A - NCPC
B - GARAGE (39·0)
C - WAREHOUSE (40·0)
D - NURSING STATION(62·0)
E - TRANSIENT CENTRE(360
F - SCHOOL (129·0)
G - CO-OP (96·0)
H - HOTEL (20·0)
I - COMMUNITY HALL(44·0)
J - COMMUNITY COMPLEX (144·0)
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
SCALE-1:2000
37mmø
62mmø
75mmø
UTILITY R/W
LOT 74
LOT 73
LOT 72
TANKS
DILLON
REPULSE BAY
FIG No
D34


SACHS HARBOUR
LEGEND
A - NCPC
B - CO-OP STORE & OFFICE (32.8)
C - COMMUNITY HALL (95.0)
D - GARAGE (140.0)
E - GARAGE (98.7)
F - SCHOOL (110.0)
SCALE 1:2000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
ANTENNA
BALL PARK
TANKS
37mm ø
50mm ø
87mm ø
67mm ø
75mm
A
B
C
D
E
F

DILLON

SACHS HARBOUR

FIG No D35


BLOCK 1
BLOCK 2
BLOCK 3
BLOCK 4
BLOCK 5
BLOCK 6
BLOCK 8
LOT 2
A
B
C
D
E
F
ALTERNATIVE 1
ALTERNATIVE 2
50mm ϕ
62mm ϕ

LEGEND

A - NCPC
B - 2-BAY GARAGE*
C - CO-OP (126.0)
D - ADMINISTRATION OFFICE (112.0)
E - NEW SCHOOL*
F - NEW NURSING STATION*

SCALE 1:1500

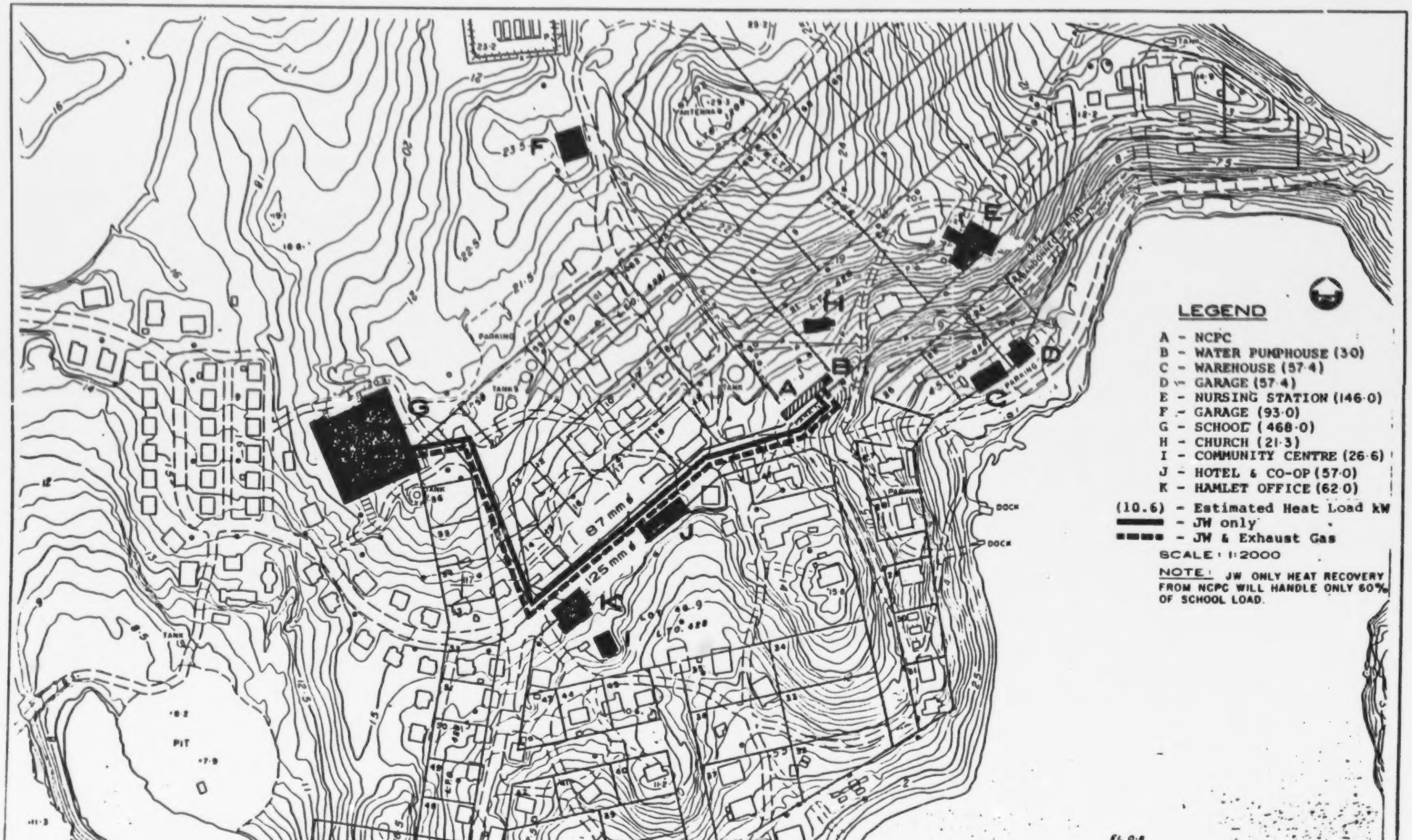
(10.6) - Estimated Heat Load kW
━━ -JJW only
▬ ▬ - JW & Exhaust Gas
* - Size Unknown

NOTE: Either Alternative 1 or Alternative 2 can be utilized. Alternative 1 is preferred because School is a new building and heating system can be best designed to more fully utilize recoverable heat.

DILLON

SNOWDRIFT

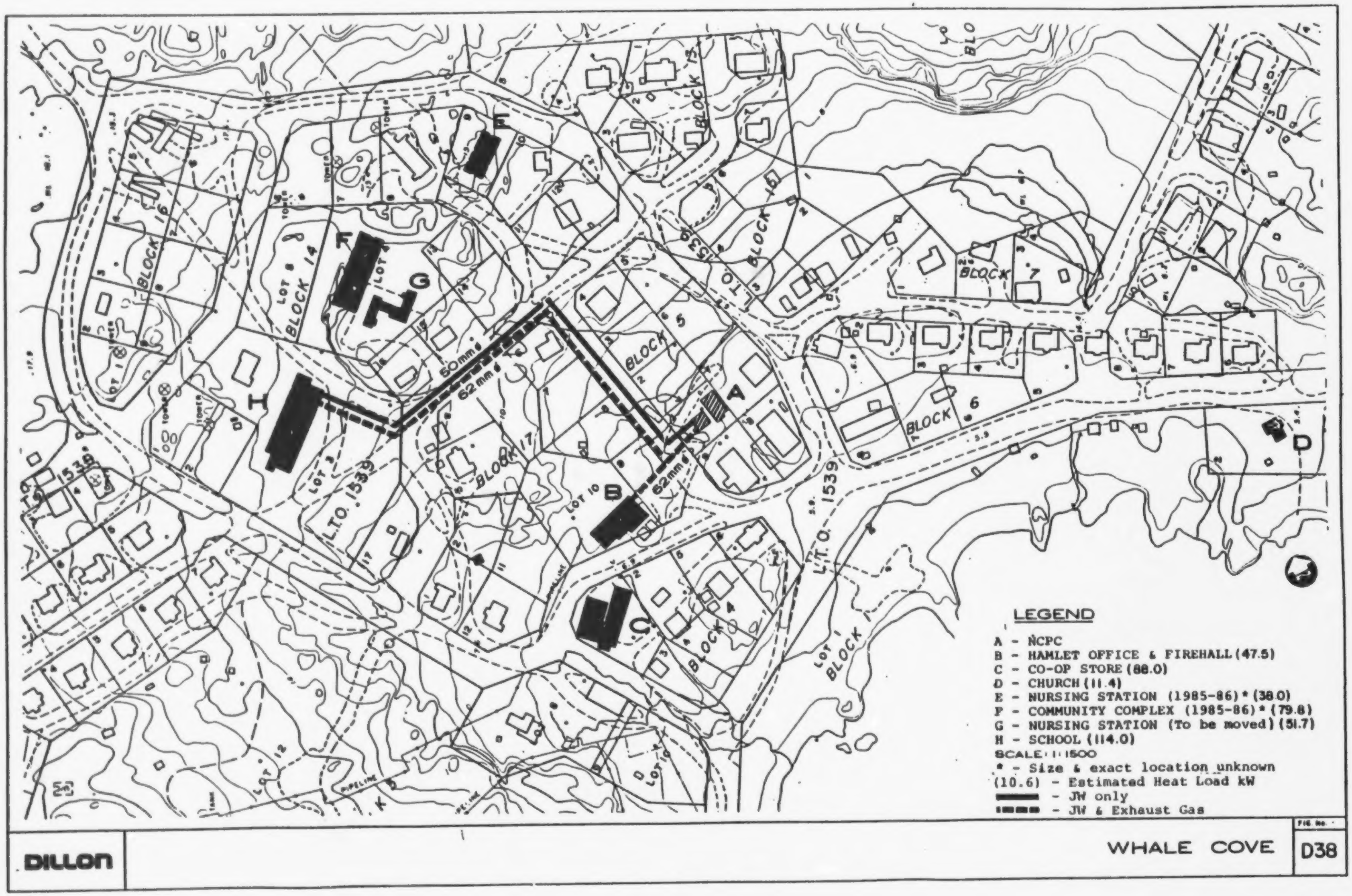
FIG. No. D36

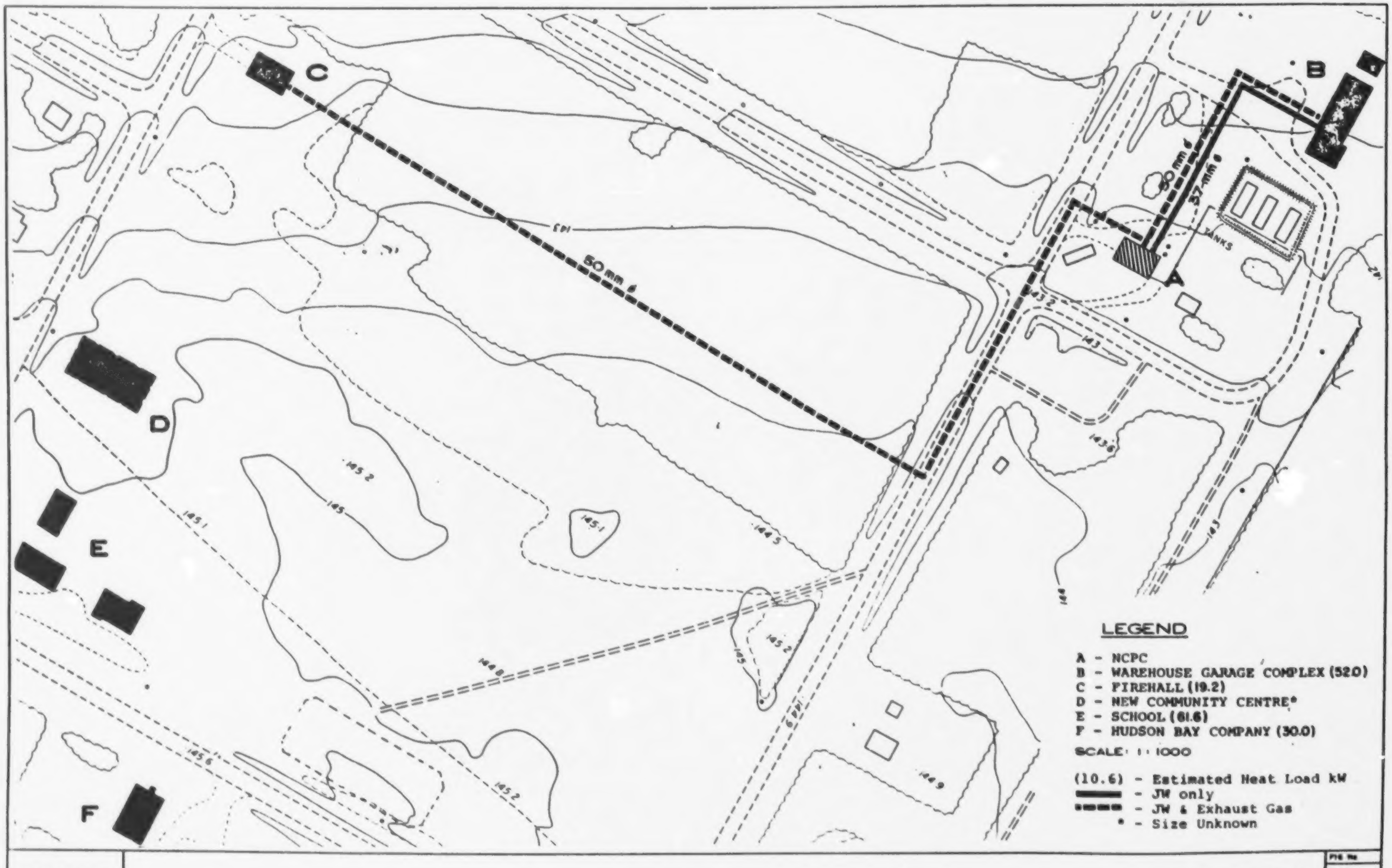

LEGEND
A - NCPC
B - WATER PUMPHOUSE (3.0)
C - WAREHOUSE (57.4)
D - GARAGE (57.4)
E - NURSING STATION (146.0)
F - GARAGE (93.0)
G - SCHOOL (468.0)
H - CHURCH (21.3)
I - COMMUNITY CENTRE (26.6)
J - HOTEL & CO-OP (57.0)
K - HAMLET OFFICE (62.0)
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
SCALE : 1:2000
NOTE : JW ONLY HEAT RECOVERY FROM NCPC WILL HANDLE ONLY 60% OF SCHOOL LOAD.
A
B
C
D
E
F
G
H
J
K
87 mm ø
125 mm ø
DOCK
DOCK
PARKING
PARKING
TANK
PIT

DILLON

SPENCE BAY

FIG No
037


LEGEND
A - NCPC
B - HAMLET OFFICE & FIREHALL (47.5)
C - CO-OP STORE (88.0)
D - CHURCH (11.4)
E - NURSING STATION (1985-86)* (38.0)
F - COMMUNITY COMPLEX (1985-86)* (79.8)
G - NURSING STATION (To be moved) (51.7)
H - SCHOOL (114.0)
SCALE 1:1500
* - Size & exact location unknown
(10.6) - Estimated Heat Load kW
- JW only
- JW & Exhaust Gas
A
B
C
D
E
F
G
H
50mm
62mm
62mm
BLOCK 4
BLOCK 5
BLOCK 6
BLOCK 7
BLOCK 13
BLOCK 14
BLOCK 15
BLOCK 16
BLOCK 17
BLOCK 1
LOT 1
LOT 3
LOT 8
LOT 10
LOT 12
L.T.O. 1539
DILLON
WHALE COVE
FIG. No.
D38


A
B
C
D
E
F
90 mm ø
37 mm ø
50 mm ø
TANKS
143.2
143
143.6
144.5
144.8
144.9
145
145.1
145.2
145.6
LEGEND
A - NCPC
B - WAREHOUSE GARAGE COMPLEX (52.0)
C - FIREHALL (19.2)
D - NEW COMMUNITY CENTRE*
E - SCHOOL (61.6)
F - HUDSON BAY COMPANY (30.0)
SCALE: 1:1000
(10.6) - Estimated Heat Load kW
▬ - JW only
▬ ▬ - JW & Exhaust Gas
* - Size Unknown
DILLON
WRIGLEY
D39

APPENDIX "D-2"

RELATIONSHIP BETWEEN AVERAGE MONTHLY ELECTRICAL AND TOTAL MONTHLY SUNSHINE HOURS

It is expected that the annual load factor would fluctuate throughout the year. Because much of the electrical power is used for lighting, it may be possible to relate the load factor to average monthly sunshine hours. A typical sample of average monthly sunlight hours from four of the 39 sites is presented in Figure D40. These four sites were selected as they represent the extremes in the average total sunshine hours and all sites fall within these extremes. Based on the lower graph in Figure D40, which shows average sunshine hours per month as a percentage of the total hours per month, a maximum fluctuation in the load factor of up to 40 per cent could be expected if all electrical power was used for lighting. A review of the fluctuation in load for Lac La Martre and Cambridge Bay as presented in Table D1 shows that for Lac La Martre, the average load factor from January 19 to 31 was 55.6 per cent. This translates to a 33 per cent increase in the average annual load forecast and compares with the maximum fluctuation of 30 per cent (based on the difference between the maximum sunshine hours for June (55 per cent) and the per cent sunshine hours/year of 25.6 per cent (55 hours for June - 25.6 hours average). For Cambridge Bay, however, the average load factor for January 19 to 31 is 53.2. It does not show the same close relationship between load factor and percentage monthly sunshine hours which ranges from an annual average of 18.5 per cent to a maximum of 34 per cent.

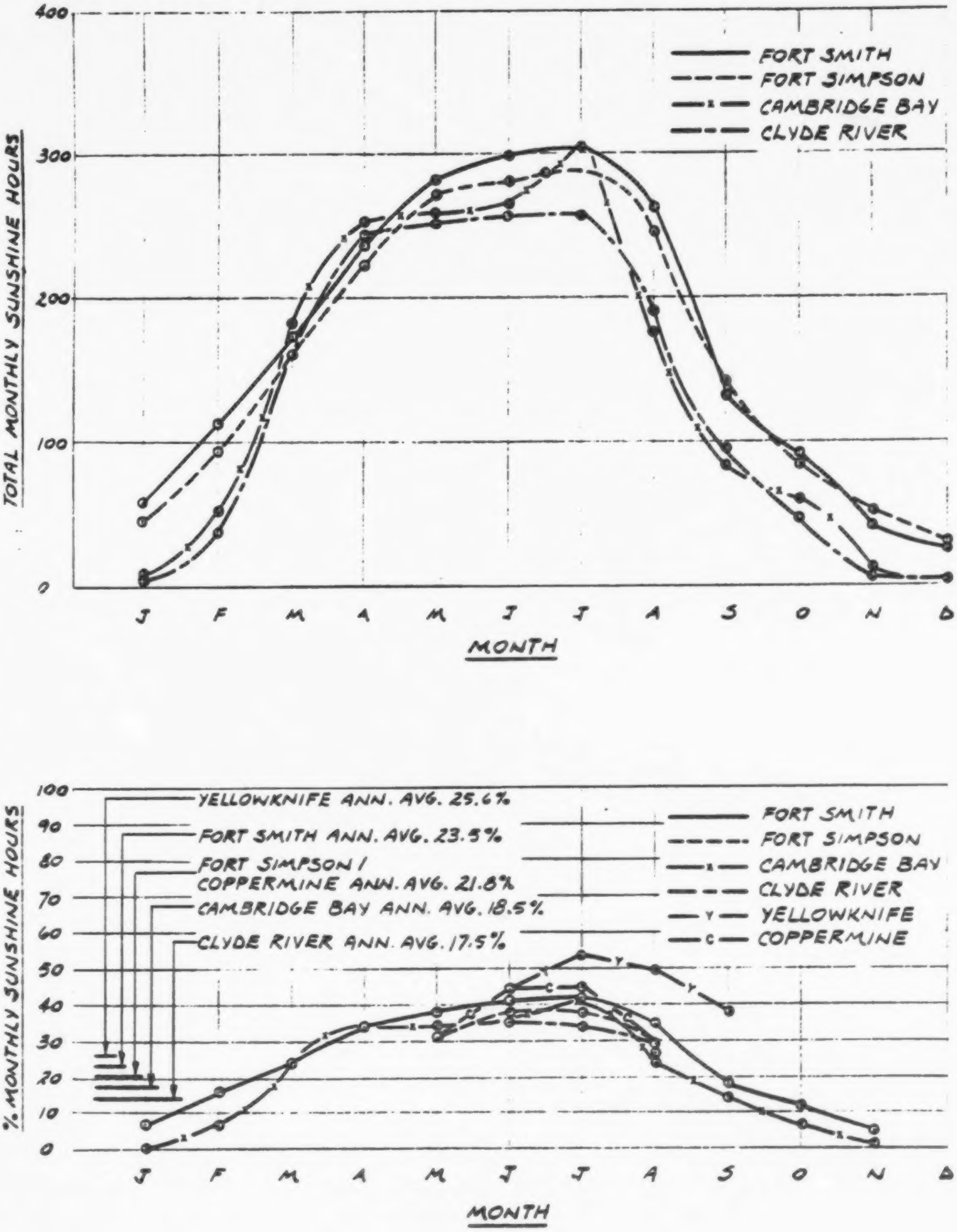
TABLE D1

LOAD FACTORS

	Lac La Martre		Cambridge Bay	
Date	Average Load Factor (%)	(1) Calculated Load Factor (%)	Average Load Factor (%)	(1) Calculate Load Factor (%)
January 19	42		54	49
January 20	42	46	54	56
January 21	42	58	54	52
January 22	42	57	54	53
January 23	42	48	54	55
January 24	42	61	54	53
January 25	42	59	54	52
January 26	42	52	54	53
January 27	42	58	54	58
January 28	42	62	54	56.4
January 29	42	59	54	52
January 30	42	46	54	57.2
January 31	42	62	54	44
Average	42	55.6	54	53.2

(1) Load factor calculated by taking total kWh produced per day divided by 24 hours and the forecast peak load.

While the relationship does exist between the fluctuation in the monthly per cent sunshine hours from the annual average for Lac La Martre, a similar one to one relationship does not exist for Cambridge Bay. It would be misleading, therefore, to generalize and modify the load factor by the fluctuations between the monthly percentage of sunshine hours and the annual percentage of sunshine hours. Consequently while Table D2 represents the available residual heat from each site based on the average annual load factors forecast by NCPC and the average demand for January 1984 load factor, it is suggested that the more conservative values calculated using the annual NCPC load factor be used to design the heat recovery and distribution system until more accurate values can be presented.



DILLON	MONTHLY TOTAL SUNSHINE HOURS	FIG. No. D40

TABLE D2

Site	Total Installed Diesel Generator Capacity kW	Forecast Peak Electrical Load kW	Modified Load Factor %	Heat Available From JW Loop (1.1 kW/kW) kW	Heat Available From Ex Gas (0.7 kW/kW) kW	Total Heat Available kW
		85-86		85-86	85-86	85-86
Aklavik	1500	577	50	317	202	519
Arctic Bay	1050	353	44	171	109	280
Arctic Red River	280	69	69	52	33	86
Baker Lake	2174	839	67	618	393	1012
Broughton Island	630	231	63	160	102	262
Cambridge Bay	2375	1044	56	643	409	1052
Cape Dorset	1500	611	55	370	235	605
Chesterfield Inlet	650	199	52	114	72	186
Clyde River	1100	322	58	205	131	336
Coppermine	1575	676	51	379	241	621
Coral Harbour[1]	1350	655	53	382	243	625
Eskimo Point	1800	743	61	499	317	816
Fort Franklin	800	401	45	198	126	325
Fort Good Hope	900	349	45	173	110	283
Fort Liard	735	138	72	109	70	179
Fort McPherson	1280	634	48	335	213	548
Fort Norman	950	320	46	162	103	265
Fort Simpson	5485	834	78	716	455	1171
Gjda Haven	1160	449	48	237	151	388
Grise Fiord	415	128	50	70	45	115
Hall Beach	785	230	65	164	105	269
Holman Island	850	263	47	136	87	222
Igloolik	1200	543	56	334	213	547
Jean Marie River	61	19	34	9	6	15
Lac La Martre		171	54	102	65	166
Lake Harbour	750	214	62	146	93	239
Nahanni Butte	151	21	68	16	10	26
Pangnirtung	1800	671	49	362	230	592
Paulatuk	575	207	41	93	59	153
Pelly Bay	800	228	50	125	80	205
Pond Inlet	1620	696	49	375	239	614
Rae Lakes	260	86	41	39	25	63
Rankin Inlet	2720	1572	65	1124	715	1839
Repulse Bay	750	218	63	151	96	247
Sachs Harbour	800	255	56	157	100	257
Snowdrift	430	140	58	89	57	146
Spence Bay	900	512	48	270	172	442
Whale Cove	650	166	57	104	66	170
Wrigley	480	52	89	51	32	83

Notes: [1] 600 kW downtown, 750 kW by MOT.

APPENDIX "E.1"

CAPITAL COSTS AND DETAILED CALCULATIONS

AKLAVIK

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	96250.00
-Ducting Modifications		N.A.		13400.00
-Valves, Sensors and Controllers		N.A.		12390.00
-J. W. Loop				
-Plate Heat Exchanger		9200.00		9200.00
-J. W. Recirculating Booster Pumps		3920.00		3920.00
-Control Valves and Sensors		3025.00		6050.00
-Valves		8600.00		10836.00
-Pipe and Fittings		1560.00		3120.00
-Pipe Insulation		1320.00		2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		6500.00		6500.00
Distribution System				
-Outdoor Piping		73320.00		92120.00
-Valves		4100.00		7750.00
-Recirculation Pumps		4200.00		4200.00
End User Connection				
-Motorized Valves, Sensors and Controls		3025.00		5450.00
-Piping and Fittings		2600.00		4200.00
-Pipe Insulation		2200.00		3000.00
-Shut-Off Valves		7100.00		8950.00
-Pumps		4200.00		4600.00
Subtotal Cost	$	134870.00	$	294576.00
Overhead and Profit (20%)	$	26974.00	$	58915.20
Northern Allowance (1)	$	84158.38	$	183815.42
Contingency and Engineering (25%)	$	61500.72	$	134326.66
Total Estimated 1985 Cost	$	307503.60	$	671633.28

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	4	6	" diameter
Dist pipe:	940	940	' long (NCPC to user)
Dist pipe:	4	5	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.52

ARCTIC BAY

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 43900.00
-Ducting Modifications	N.A.	5500.00
-Valves, Sensors and Controllers	N.A.	5300.00
-J. W. Loop		
-Plate Heat Exchanger	6900.00	6900.00
-J. W. Recirculating Booster Pumps	3060.00	3060.00
-Control Valves and Sensors	2200.00	4400.00
-Valves	7835.00	9872.00
-Pipe and Fittings	900.00	1800.00
-Pipe Insulation	870.00	1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6000.00	6000.00
Distribution System		
-Outdoor Piping	60520.00	118950.00
-Valves	2840.00	4100.00
-Recirculation Pumps	3200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	2200.00	12100.00
-Piping and Fittings	1500.00	10400.00
-Pipe Insulation	1450.00	8800.00
-Shut-Off Valves	4975.00	28400.00
-Pumps	3200.00	16800.00
Subtotal Cost	$ 107650.00	$ 292222.00
Overhead and Profit (20%)	$ 21530.00	$ 58444.40
Northern Allowance (1)	$ 99468.60	$ 270013.13
Contingency and Engineering (25%)	$ 57162.15	$ 155169.68
Total Estimated 1985 Cost	$ 285810.75	$ 775849.41

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	3	4	" diameter
Dist pipe:	690	1525	' long (NCPC to user)
Dist pipe:	3	4	" diameter (NCPC to user)
No. of users:	1	4	

(3)NCI = 1.77

ARCTIC RED RIVER

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 15900.00
-Ducting Modifications	N.A.	1400.00
-Valves, Sensors and Controllers	N.A.	5000.00
-J. W. Loop		
-Plate Heat Exchanger	6450.00	6450.00
-J. W. Recirculating Booster Pumps	2750.00	2750.00
-Control Valves and Sensors	1260.00	2520.00
-Valves	2240.00	2822.00
-Pipe and Fittings	447.00	894.00
-Pipe Insulation	420.00	840.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	5100.00	5100.00
Distribution System		
-Outdoor Piping	17860.00	36540.00
-Valves	850.00	1070.00
-Recirculation Pumps	2750.00	3000.00
End User Connection		
-Motorized Valves, Sensors and Controls	1200.00	2520.00
-Piping and Fittings	620.00	1490.00
-Pipe Insulation	700.00	1400.00
-Shut-Off Valves	1480.00	3680.00
-Pumps	2750.00	6000.00
Subtotal Cost	$ 46877.00	$ 99376.00
Overhead and Profit (20%)	$ 9375.40	$ 19875.20
Northern Allowance (1)	$ 29251.25	$ 62010.62
Contingency and Engineering (25%)	$ 21375.91	$ 45315.46
Total Estimated 1985 Cost	$ 106879.56	$ 226577.28

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	2	2	" diameter
User pipe:	1.5	2	" diameter
Dist pipe:	380	630	' long (NCPC to user)
Dist pipe:	1.5	2	" diameter (NCPC to user)
No. of users:	1	2	

(3)NCI = 1.52

BAKER LAKE		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	141300.00
-Ducting Modifications		N.A.		11100.00
-Valves, Sensors and Controllers		N.A.		14300.00
-J. W. Loop				
-Plate Heat Exchanger		11950.00		11950.00
-J. W. Recirculating Booster Pumps		4320.00		4320.00
-Control Valves and Sensors		5450.00		10900.00
-Valves		10750.00		13545.00
-Pipe and Fittings		2520.00		5040.00
-Pipe Insulation		1800.00		3600.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		7600.00		7600.00
Distribution System				
-Outdoor Piping		241080.00		315070.00
-Valves		7750.00		5350.00
-Recirculation Pumps		4200.00		4600.00
End User Connection				
-Motorized Valves, Sensors and Controls		28875.00		32700.00
-Piping and Fittings		29400.00		25200.00
-Pipe Insulation		21000.00		18000.00
-Shut-Off Valves		96250.00		53700.00
-Pumps		29400.00		27600.00
Subtotal Cost	$	502345.00	$	705875.00
Overhead and Profit (20%)	$	100469.00	$	141175.00
Northern Allowance (1)	$	373744.68	$	525171.00
Contingency and Engineering (25%)	$	244139.67	$	343055.25
Total Estimated 1985 Cost	$	1220698.35	$	1715276.25

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	6	6	" diameter
User pipe:	5	6	" diameter
Dist pipe:	2460	3215	long (NCPC to user)
Dist pipe:	5	6	" diameter (NCPC to user)
No. of users:	7	6	

(3)NCI = 1.62

BROUGHTON ISLAND	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 43800.00
-Ducting Modifications	N.A.	2200.00
-Valves, Sensors and Controllers	N.A.	5250.00
-J. W. Loop		
-Plate Heat Exchanger	6900.00	6900.00
-J. W. Recirculating Booster Pumps	3060.00	3060.00
-Control Valves and Sensors	2200.00	4400.00
-Valves	7835.00	9872.00
-Pipe and Fittings	900.00	1800.00
-Pipe Insulation	870.00	1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6000.00	6000.00
Distribution System		
-Outdoor Piping	27880.00	61620.00
-valves	2840.00	4100.00
-Recirculation Pumps	3200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	2200.00	12100.00
-Piping and Fittings	1500.00	10400.00
-Pipe Insulation	1450.00	8800.00
-Shut-Off Valves	4975.00	28400.00
-Pumps	3200.00	16800.00
Subtotal Cost	$ 75010.00	$ 231442.00
Overhead and Profit (20%)	$ 15002.00	$ 46288.40
Northern Allowance (1)	$ 67509.00	$ 208297.80
Contingency and Engineering (25%)	$ 39380.25	$ 121507.05
Total Estimated 1985 Cost	$ 196901.25	$ 607535.25

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	3	4	" diameter
Dist pipe:	410	790	' long (NCPC to user)
Dist pipe:	3	4	" diameter (NCPC to user)
No. of users:	1	4	

(3)NCI = 1.75

CAPE DORSET

	Jacket Water Heat Recovery Only	Jacket Water Plus Exnaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 96250.00
-Ducting Modifications	N.A.	8900.00
-Valves, Sensors and Controllers	N.A.	12400.00
-J. W. Loop		
-Plate Heat Exchanger	9200.00	9200.00
-J. W. Recirculating Booster Pumps	3920.00	3920.00
-Control Valves and Sensors	3025.00	6050.00
-Valves	8600.00	10836.00
-Pipe and Fittings	1560.00	3120.00
-Pipe Insulation	1320.00	2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6500.00	6500.00
Distribution System		
-Outdoor Piping	40950.00	61250.00
-Valves	4100.00	7750.00
-Recirculation Pumps	4200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	15125.00	4125.00
-Piping and Fittings	13000.00	4200.00
-Pipe Insulation	11000.00	3000.00
-Shut-Off Valves	35500.00	13750.00
-Pumps	21000.00	4200.00
Subtotal Cost	$ 179000.00	$ 262291.00
Overhead and Profit (20%)	$ 35800.00	$ 52458.20
Northern Allowance (1)	$ 135324.00	$ 198292.00
Contingency and Engineering (25%)	$ 87531.00	$ 128260.30
Total Estimated 1985 Cost	$ 437655.00	$ 641301.50

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	4	5	" diameter
Dist pipe:	525	625	' long (NCPC to user)
Dist pipe:	4	5	" diameter (NCPC to user)
No. of users:	5	1	

(3)NCI = 1.63

CHESTERFIELD INLET	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 43850.00
-Ducting Modifications	N.A.	2100.00
-Valves, Sensors and Controllers	N.A.	5250.00
-J. W. Loop		
-Plate Heat Exchanger	6450.00	6450.00
-J. W. Recirculating Booster Pumps	2850.00	2850.00
-Control Valves and Sensors	2175.00	4350.00
-Valves	5060.00	6375.00
-Pipe and Fittings	803.00	1605.00
-Pipe Insulation	690.00	1380.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	5500.00	5500.00
Distribution System		
-Outdoor Piping	188500.00	171700.00
-Valves	1070.00	2940.00
-Recirculation Pumps	3000.00	3200.00
End User Connection		
-Motorized Valves, Sensors and Controls	2520.00	2200.00
-Piping and Fittings	1490.00	1500.00
-Pipe Insulation	1400.00	1450.00
-Shut-Off Valves	3680.00	4975.00
-Pumps	6000.00	3200.00
Subtotal Cost	$ 231188.00	$ 270775.00
Overhead and Profit (20%)	$ 46237.60	$ 54155.00
Northern Allowance (1)	$ 180326.64	$ 211204.50
Contingency and Engineering (25%)	$ 114438.06	$ 134033.63
Total Estimated 1985 Cost	$ 572190.30	$ 670168.13

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	2.5	2.5	" diameter
User pipe:	2	3	" diameter
Dist pipe:	3250	2525	long (NCPC to user)
Dist pipe:	2	3	" diameter (NCPC to user)
No. of users:	2	1	

(3)NCI = 1.65

CLYDE RIVER

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 69400.00
-Ducting Modifications	N.A.	6100.00
-Valves, Sensors and Controllers	N.A.	7200.00
-J. W. Loop		
-Plate Heat Exchanger	9200.00	9200.00
-J. W. Recirculating Booster Pumps	3920.00	3920.00
-Control Valves and Sensors	3025.00	6050.00
-Valves	8600.00	10836.00
-Pipe and Fittings	1560.00	3120.00
-Pipe Insulation	1320.00	2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6500.00	6500.00
Distribution System		
-Outdoor Piping	135720.00	215280.00
-Valves	4940.00	4100.00
-Recirculation Pumps	4000.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	13200.00	16150.00
-Piping and Fittings	13200.00	15600.00
-Pipe Insulation	10800.00	13200.00
-Shut-Off Valves	51600.00	42600.00
-Pumps	24000.00	25200.00
Subtotal Cost	$ 291585.00	$ 463296.00
Overhead and Profit (20%)	$ 58317.00	$ 92659.20
Northern Allowance (1)	$ 262426.50	$ 416966.40
Contingency and Engineering (25%)	$ 153082.13	$ 243230.40
Total Estimated 1985 Cost	$ 765410.63	$ 1216152.00

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	3.5	4	" diameter
Dist pipe:	1740	2760	' long (NCPC to user)
Dist pipe:	3.5	4	" diameter (NCPC to user)
No. of users:	6	6	
(3)NCI =	1.75		

COPPERMINE	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 96250.00
-Ducting Modifications	N.A.	12400.00
-Valves, Sensors and Controllers	N.A.	12100.00
-J. W. Loop		
-Plate Heat Exchanger	11950.00	11950.00
-J. W. Recirculating Booster Pumps	4320.00	4320.00
-Control Valves and Sensors	5450.00	10900.00
-Valves	10750.00	13545.00
-Pipe and Fittings	2520.00	5040.00
-Pipe Insulation	1800.00	3600.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	7600.00	7600.00
Distribution System		
-Outdoor Piping	148200.00	205800.00
-Valves	4100.00	7750.00
-Recirculation Pumps	4200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	6050.00	16350.00
-Piping and Fittings	5200.00	12600.00
-Pipe Insulation	4400.00	9000.00
-Shut-Off Valves	14200.00	26650.00
-Pumps	8400.00	13200.00
Subtotal Cost	$ 239140.00	$ 474055.00
Overhead and Profit (20%)	$ 47828.00	$ 94811.00
Northern Allowance (1)	$ 200877.60	$ 398206.20
Contingency and Engineering (25%)	$ 121961.40	$ 241768.05
Total Estimated 1985 Cost	$ 609807.00	$ 1208840.25

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	6	6	" diameter
User pipe:	4	6	" diameter
Dist pipe:	1900	2100	' long (NCPC to user)
Dist pipe:	4	5	" diameter (NCPC to user)
No. of users:	2	3	

(3)NCI = 1.7

CORAL HARBOUR

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 69400.00
-Ducting Modifications	N.A.	3500.00
-Valves, Sensors and Controllers	N.A.	10500.00
-J. W. Loop		
-Plate Heat Exchanger	11950.00	11950.00
-J. W. Recirculating Booster Pumps	4320.00	4320.00
-Control Valves and Sensors	5450.00	10900.00
-Valves	10750.00	13545.00
-Pipe and Fittings	2520.00	5040.00
-Pipe Insulation	1800.00	3600.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	7600.00	7600.00
Distribution System		
-Outdoor Piping	109980.00	131810.00
-Valves	4100.00	7750.00
-Recirculation Pumps	4200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	6050.00	5450.00
-Piping and Fittings	5200.00	4200.00
-Pipe Insulation	4400.00	3000.00
-Shut-Off Valves	14200.00	8950.00
-Pumps	8400.00	4600.00
Subtotal Cost	$ 200920.00	$ 310315.00
Overhead and Profit (20%)	$ 40184.00	$ 62063.00
Northern Allowance (1)	$ 159128.64	$ 245769.48
Contingency and Engineering (25%)	$ 100058.16	$ 154536.87
Total Estimated 1985 Cost	$ 500290.80	$ 772684.35

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	6	6	" diameter
User pipe:	4	6	" diameter
Dist pipe:	1410	1345	' long (NCPC to user)
Dist pipe:	4	5	" diameter (NCPC to user)
No. of users:	2	1	

(3)NCI = 1.66

ESKIMO POINT	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 96250.00
-Ducting Modifications	N.A.	10100.00
-Valves, Sensors and Controllers	N.A.	12400.00
-J. W. Loop		
-Plate Heat Exchanger	11950.00	11950.00
-J. W. Recirculating Booster Pumps	4320.00	4320.00
-Control Valves and Sensors	5450.00	10900.00
-Valves	10750.00	13545.00
-Pipe and Fittings	2520.00	5040.00
-Pipe Insulation	1800.00	3600.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	7600.00	7600.00
Distribution System		
-Outdoor Piping	81830.00	154350.00
-Valves	7750.00	5350.00
-Recirculation Pumps	4200.00	4600.00
End User Connection		
-Motorized Valves, Sensors and Controls	4125.00	21800.00
-Piping and Fittings	4200.00	16800.00
-Pipe Insulation	3000.00	12000.00
-Shut-Off Valves	13750.00	35800.00
-Pumps	4200.00	18400.00
Subtotal Cost	$ 167445.00	$ 444805.00
Overhead and Profit (20%)	$ 33489.00	$ 88961.00
Northern Allowance (1)	$ 118551.06	$ 314921.94
Contingency and Engineering (25%)	$ 79871.27	$ 212171.99
Total Estimated 1985 Cost	$ 399356.33	$ 1060859.93

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	6	6	" diameter
User pipe:	5	6	" diameter
Dist pipe:	835	1575	' long (NCPC to user)
Dist pipe:	5	6	" diameter (NCPC to user)
No. of users:	1	4	

(3)NCI = 1.59

FORT FRANKLIN

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 69400.00
-Ducting Modifications	N.A.	4000.00
-Valves, Sensors and Controllers	N.A.	10500.00
-J. W. Loop		
-Plate Heat Exchanger	9200.00	9200.00
-J. W. Recirculating Booster Pumps	3920.00	3920.00
-Control Valves and Sensors	3025.00	6050.00
-Valves	8600.00	10836.00
-Pipe and Fittings	1560.00	3120.00
-Pipe Insulation	1320.00	2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6500.00	6500.00
Distribution System		
-Outdoor Piping	42500.00	53820.00
-Valves	2840.00	4100.00
-Recirculation Pumps	3200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	2200.00	6050.00
-Piping and Fittings	1500.00	5200.00
-Pipe Insulation	1450.00	4400.00
-Shut-Off Valves	4975.00	14200.00
-Pumps	3200.00	8400.00
Subtotal Cost	$ 95990.00	$ 226536.00
Overhead and Profit (20%)	$ 19198.00	$ 45307.20
Northern Allowance (1)	$ 63353.40	$ 149513.76
Contingency and Engineering (25%)	$ 44635.35	$ 105339.24
Total Estimated 1985 Cost	$ 223176.75	$ 526696.20

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	3	4	" diameter
Dist pipe:	625	690	' long (NCPC to user)
Dist pipe:	3	4	" diameter (NCPC to user)
No. of users:	1	2	

(3)NCI = 1.55

FORT GOOD HOPE

	Jacket Water Heat Recovery OnIy	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 69400.00
-Ducting Modifications	N.A.	3500.00
-Valves, Sensors and Controllers	N.A.	10500.00
-J. W. Loop		
-Plate Heat Exchanger	6900.00	6900.00
-J. W. Recirculating Booster Pumps	3060.00	3060.00
-Control Valves and Sensors	2200.00	4400.00
-Valves	7835.00	9872.00
-Pipe and Fittings	900.00	1800.00
-Pipe Insulation	870.00	1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6000.00	6000.00
Distribution System		
-Outdoor Piping	55760.00	83460.00
-Valves	2840.00	4100.00
-Recirculation Pumps	3200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	4400.00	9075.00
-Piping and Fittings	3000.00	7800.00
-Pipe Insulation	2900.00	6600.00
-Shut-Off Valves	9950.00	21300.00
-Pumps	6400.00	12600.00
Subtotal Cost	$ 116215.00	$ 266307.00
Overhead and Profit (20%)	$ 23243.00	$ 53261.40
Northern Allowance (1)	$ 72518.16	$ 166175.57
Contingency and Engineering (25%)	$ 52994.04	$ 121435.99
Total Estimated 1985 Cost	$ 264970.20	$ 607179.96

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	3	4	" diameter
Dist pipe:	820	1070	' long (NCPC to user)
Dist pipe:	3	4	" diameter (NCPC to user)
No. of users:	2	3	

(3)NCI = 1.52

FORT LIARD

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	21000.00
-Ducting Modifications		N.A.		1400.00
-Valves, Sensors and Controllers		N.A.		5000.00
-J. W. Loop				
-Plate Heat Exchanger		6450.00		6450.00
-J. W. Recirculating Booster Pumps		2850.00		2850.00
-Control Valves and Sensors		2175.00		4350.00
-Valves		3060.00		6375.00
-Pipe and Fittings		803.00		1605.00
-Pipe Insulation		690.00		1380.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		5500.00		5500.00
Distribution System				
-Outdoor Piping		17980.00		23120.00
-Valves		1070.00		2840.00
-Recirculation Pumps		3000.00		3200.00
End User Connection				
-Motorized Valves, Sensors and Controls		1260.00		4400.00
-Piping and Fittings		745.00		3000.00
-Pipe Insulation		700.00		2900.00
-Shut-Off Valves		1840.00		9950.00
-Pumps		3000.00		6400.00
Subtotal Cost	$	53123.00	$	111720.00
Overhead and Profit (20%)	$	10624.60	$	22344.00
Northern Allowance (1)	$	28048.94	$	58968.16
Contingency and Engineering (25%)	$	22949.14	$	48263.04
Total Estimated 1985 Cost	$	114745.68	$	241315.20

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	2.5	2.5	" diameter
User pipe:	2	3	" diameter
Dist pipe:	310	340	' long (NCPC to user)
Dist pipe:	2	3	" diameter (NCPC to user)
No. of users:	1	2	

(3)NCI = 1.44

FORT McPHERSON	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 96250.00
-Ducting Modifications	N.A.	9200.00
-Valves, Sensors and Controllers	N.A.	12800.00
-J. W. Loop		
-Plate Heat Exchanger	9200.00	9200.00
-J. W. Recirculating Booster Pumps	3920.00	3920.00
-Control Valves and Sensors	3025.00	6050.00
-Valves	8600.00	10836.00
-Pipe and Fittings	1560.00	3120.00
-Pipe Insulation	1320.00	2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6500.00	6500.00
Distribution System		
-Outdoor Piping	31980.00	40180.00
-Valves	4100.00	7750.00
-Recirculation Pumps	4200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	3025.00	5450.00
-Piping and Fittings	2600.00	4200.00
-Pipe Insulation	2200.00	3000.00
-Shut-Off Valves	7100.00	8950.00
-Pumps	4200.00	4600.00
Subtotal Cost	$ 93530.00	$ 238846.00
Overhead and Profit (20%)	$ 18706.00	$ 47769.20
Northern Allowance (1)	$ 58362.72	$ 149039.90
Contingency and Engineering (25%)	$ 42649.68	$ 108913.78
Total Estimated 1985 Cost	$ 213248.40	$ 544568.88

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	4	6	" diameter
Dist pipe:	410	410	' long (NCPC to user)
Dist pipe:	4	5	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.52

FORT NORMAN

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	43850.00
-Ducting Modifications		N.A.		4200.00
-Valves, Sensors and Controllers		N.A.		5800.00
-J. W. Loop				
-Plate Heat Exchanger		6900.00		6900.00
-J. W. Recirculating Booster Pumps		3060.00		3060.00
-Control Valves and Sensors		2200.00		4400.00
-Valves		7835.00		7872.00
-Pipe and Fittings		900.00		1800.00
-Pipe Insulation		870.00		1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		6000.00		6000.00
Distribution System				
-Outdoor Piping		53940.00		72540.00
-Valves		2360.00		4940.00
-Recirculation Pumps		3100.00		4000.00
End User Connection				
-Motorized Valves, Sensors and Controls		2175.00		5025.00
-Piping and Fittings		1338.00		2600.00
-Pipe Insulation		1150.00		2200.00
-Shut-Off Valves		4200.00		7100.00
-Pumps		3100.00		4200.00
Subtotal Cost	$	99128.00	$	188227.00
Overhead and Profit (20%)	$	19825.60	$	37645.40
Northern Allowance (1)	$	59476.80	$	112936.20
Contingency and Engineering (25%)	$	44607.60	$	84702.15
Total Estimated 1985 Cost	$	223038.00	$	423510.75

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	2.5	4	" diameter
Dist pipe:	930	930	' long (NCPC to user)
Dist pipe:	2.5	3.5	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.5

FORT SIMPSON		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	119600.00
-Ducting Modifications		N.A.		11400.00
-Valves, Sensors and Controllers		N.A.		13900.00
-J. W. Loop				
-Plate Heat Exchanger		11950.00		11950.00
-J. W. Recirculating Booster Pumps		4320.00		4320.00
-Control Valves and Sensors		5450.00		10900.00
-Valves		10750.00		13545.00
-Pipe and Fittings		2520.00		5040.00
-Pipe Insulation		1800.00		3600.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		7600.00		7600.00
Distribution System				
-Outdoor Piping		199430.00		279600.00
-Valves		5350.00		12900.00
-Recirculation Pumps		4600.00		5000.00
End User Connection				
-Motorized Valves, Sensors and Controls		16350.00		21800.00
-Piping and Fittings		12600.00		16800.00
-Pipe Insulation		9000.00		12000.00
-Shut-Off Valves		26850.00		35800.00
-Pumps		13800.00		18400.00
Subtotal Cost	$	332370.00	$	604155.00
Overhead and Profit (20%)	$	66474.00	$	120831.00
Northern Allowance (1)	$	151560.72	$	275494.68
Contingency and Engineering (25%)	$	137601.18	$	250120.17
Total Estimated 1985 Cost	$	688005.90	$	1250600.85

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	6	6	" diameter
User pipe:	6	6	" diameter
Dist pipe:	2035	2330	' long (NCPC to user)
Dist pipe:	6	8	" diameter (NCPC to user)
No. of users:	3	4	

(3)NCI = 1.38

GJOA HAVEN		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	96250.00
-Ducting Modifications		N.A.		3350.00
-Valves, Sensors and Controllers		N.A.		10500.00
-J. W. Loop				
-Plate Heat Exchanger		9200.00		9200.00
-J. W. Recirculating Booster Pumps		3920.00		3920.00
-Control Valves and Sensors		3025.00		6050.00
-Valves		8600.00		10836.00
-Pipe and Fittings		1560.00		3120.00
-Pipe Insulation		1320.00		2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		6500.00		6500.00
Distribution System				
-Outdoor Piping		115050.00		115050.00
-Valves		4940.00		4100.00
-Recirculation Pumps		4000.00		4200.00
End User Connection				
-Motorized Valves, Sensors and Controls		4400.00		6050.00
-Piping and Fittings		4400.00		5200.00
-Pipe Insulation		3600.00		4400.00
-Shut-Off Valves		17200.00		14200.00
-Pumps		8000.00		8400.00
Subtotal Cost	$	195715.00	$	313966.00
Overhead and Profit (20%)	$	39143.00	$	62793.20
Northern Allowance (1)	$	185537.82	$	297639.77
Contingency and Engineering (25%)	$	105098.96	$	168599.74
Total Estimated 1985 Cost	$	525494.78	$	842998.71

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	' diameter
User pipe:	3.5	4	" diameter
Dist pipe:	1475	1475	' long (NCPC to user)
Dist pipe:	3.5	4	" diameter (NCPC to user)
No. of users:	2	2	

(3)NCI = 1.79

GRISE FIORD

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	30900.00
-Ducting Modifications		N.A.		2300.00
-Valves, Sensors and Controllers		N.A.		10500.00
-J. W. Loop				
-Plate Heat Exchanger		6450.00		6450.00
-J. W. Recirculating Booster Pumps		2750.00		2750.00
-Control Valves and Sensors		1260.00		2520.00
-Valves		2240.00		2822.00
-Pipe and Fittings		447.00		894.00
-Pipe Insulation		420.00		840.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		5100.00		5100.00
Distribution System				
-Outdoor Piping		36250.00		46400.00
-Valves		1070.00		2360.00
-Recirculation Pumps		3000.00		3100.00
End User Connection				
-Motorized Valves, Sensors and Controls		2520.00		8700.00
-Piping and Fittings		1490.00		5352.00
-Pipe Insulation		1400.00		4600.00
-Shut-Off Valves		3680.00		16800.00
-Pumps		6000.00		12400.00
Subtotal Cost	$	74077.00	$	164788.00
Overhead and Profit (20%)	$	14815.40	$	32957.60
Northern Allowance (1)	$	80892.08	$	179948.50
Contingency and Engineering (25%)	$	42446.12	$	94423.52
Total Estimated 1985 Cost	$	212230.61	$	472117.62

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	2	2	" diameter
User pipe:	2	2.5	" diameter
Dist pipe:	625	800	' long (NCPC to user)
Dist pipe:	2	2.5	" diameter (NCPC to user)
No. of users:	2	4	

(3)NCI = 1.91

HALL BEACH

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 43850.00
-Ducting Modifications	N.A.	2100.00
-Valves, Sensors and Controllers	N.A.	5250.00
-J. W. Loop		
-Plate Heat Exchanger	6900.00	6900.00
-J. W. Recirculating Booster Pumps	3060.00	3060.00
-Control Valves and Sensors	2200.00	4400.00
-Valves	7835.00	9872.00
-Pipe and Fittings	900.00	1800.00
-Pipe Insulation	870.00	1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6000.00	6000.00
Distribution System		
-Outdoor Piping	53360.00	61200.00
-Valves	2360.00	2840.00
-Recirculation Pumps	3100.00	3200.00
End User Connection		
-Motorized Valves, Sensors and Controls	6525.00	6600.00
-Piping and Fittings	4014.00	4500.00
-Pipe Insulation	3450.00	4350.00
-Shut-Off Valves	12600.00	14925.00
-Pumps	9300.00	9600.00
Subtotal Cost	$ 122474.00	$ 192187.00
Overhead and Profit (20%)	$ 24494.80	$ 38437.40
Northern Allowance (1)	$ 111696.29	$ 175274.54
Contingency and Engineering (25%)	$ 64666.27	$ 101474.74
Total Estimated 1985 Cost	$ 323331.36	$ 507373.68

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	2.5	3	" diameter
Dist pipe:	920	900	' long (NCPC to user)
Dist pipe:	2.5	3	" diameter (NCPC to user)
No. of users:	3	3	

(3)NCI = 1.76

HOLMAN	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 54000.00
-Ducting Modifications	N.A.	2300.00
-Valves, Sensors and Controllers	N.A.	10000.00
-J. W. Loop		
-Plate Heat Exchanger	6900.00	6900.00
-J. W. Recirculating Booster Pumps	3060.00	3060.00
-Control Valves and Sensors	2200.00	4400.00
-Valves	7835.00	9872.00
-Pipe and Fittings	900.00	1800.00
-Pipe Insulation	870.00	1740.00
-BTU Meter, Complete with Temoerature and Flow Sensor Elements	6000.00	6000.00
Distribution System		
-Outdoor Piping	85550.00	46920.00
-Valves	2360.00	2840.00
-Recirculation Pumps	3100.00	3200.00
End User Connection		
-Motorized Valves, Sensors and Controls	10875.00	2200.00
-Piping and Fittings	6690.00	1500.00
-Pipe Insulation	5750.00	1450.00
-Shut-Off Valves	21000.00	4975.00
-Pumps	15500.00	3200.00
Subtotal Cost	$ 178590.00	$ 166357.00
Overhead and Profit (20%)	$ 35718.00	$ 33271.40
Northern Allowance (1)	$ 160731.00	$ 149721.30
Contingency and Engineering (25%)	$ 93759.75	$ 87337.43
Total Estimated 1985 Cost	$ 468798.75	$ 436667.13

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	2.5	3	" diameter
Dist pipe:	1475	690	' long (NCPC to user)
Dist pipe:	2.5	3	" diameter (NCPC to user)
No. of users:	5	1	
(3)NCI =	1.75		

IGLOOLIK

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	96250.00
-Ducting Modifications		N.A.		10000.00
-Valves, Sensors and Controllers		N.A.		12400.00
-J. W. Loop				
-Plate Heat Exchanger		9200.00		9200.00
-J. W. Recirculating Booster Pumps		3920.00		3920.00
-Control Valves and Sensors		3025.00		6050.00
-Valves		8600.00		10836.00
-Pipe and Fittings		1560.00		3120.00
-Pipe Insulation		1320.00		2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		6500.00		6500.00
Distribution System				
-Outdoor Piping		12670.00		77910.00
-Valves		4100.00		7750.00
-Recirculation Pumps		4200.00		4200.00
End User Connection				
-Motorized Valves, Sensors and Controls		3025.00		4125.00
-Piping and Fittings		2600.00		4200.00
-Pipe Insulation		2200.00		3000.00
-Shut-Off Valves		7100.00		13750.00
-Pumps		4200.00		4200.00
Subtotal Cost	$	74420.00	$	280051.00
Overhead and Profit (20%)	$	14884.00	$	56010.20
Northern Allowance (1)	$	67871.04	$	255406.51
Contingency and Engineering (25%)	$	39293.76	$	147866.93
Total Estimated 1985 Cost	$	196468.80	$	739334.64

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	4	5	" diameter
Dist pipe:	165	795	' long (NCPC to user)
Dist pipe:	4	5	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.76

LAKE HARBOUR

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 43850.00
-Ducting Modifications	N.A.	2050.00
-Valves, Sensors and Controllers	N.A.	5250.00
-J. W. Loop		
-Plate Heat Exchanger	6900.00	6900.00
-J. W. Recirculating Booster Pumps	3060.00	3060.00
-Control Valves and Sensors	2200.00	4400.00
-Valves	7835.00	9872.00
-Pipe and Fittings	900.00	1800.00
-Pipe Insulation	870.00	1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6000.00	6000.00
Distribution System		
-Outdoor Piping	15080.00	38080.00
-Valves	2360.00	2840.00
-Recirculation Pumps	3100.00	3200.00
End User Connection		
-Motorized Valves, Sensors and Controls	2175.00	6600.00
-Piping and Fittings	1338.00	4500.00
-Pipe Insulation	1150.00	4350.00
-Shut-Off Valves	4200.00	14925.00
-Pumps	3100.00	9600.00
Subtotal Cost	$ 60268.00	$ 169017.00
Overhead and Profit (20%)	$ 12053.60	$ 33803.40
Northern Allowance (1)	$ 44839.39	$ 125748.65
Contingency and Engineering (25%)	$ 29290.25	$ 82142.26
Total Estimated 1985 Cost	$ 146451.24	$ 410711.31

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	2.5	3	" diameter
Dist pipe:	260	560	' long (NCPC to user)
Dist pipe:	2.5	3	" diameter (NCPC to user)
No. of users:	1	3	

(3)NCI = 1.62

NAHANNI BUTTE	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 15900.00
-Ducting Modifications	N.A.	1350.00
-Valves, Sensors and Controllers	N.A.	5000.00
-J. W. Loop		
-Plate Heat Exchanger	3925.00	3925.00
-J. W. Recirculating Booster Pumps	2500.00	2500.00
-Control Valves and Sensors	1100.00	2200.00
-Valves	1380.00	1748.00
-Pipe and Fittings	300.00	600.00
-Pipe Insulation	360.00	720.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	3900.00	3900.00
Distribution System		
-Outdoor Piping	10800.00	10800.00
-Valves	660.00	660.00
-Recirculation Pumps	2750.00	2750.00
End User Connection		
-Motorized Valves, Sensors and Controls	1100.00	1100.00
-Piping and Fittings	500.00	500.00
-Pipe Insulation	600.00	600.00
-Shut-Off Valves	1060.00	1060.00
-Pumps	2750.00	2750.00
Subtotal Cost	$ 33685.00	$ 58063.00
Overhead and Profit (20%)	$ 6737.00	$ 11612.60
Northern Allowance (1)	$ 17785.68	$ 30657.26
Contingency and Engineering (25%)	$ 14551.92	$ 25083.22
Total Estimated 1985 Cost	$ 72759.60	$ 125416.08

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	1	1	" diameter
User pipe:	1	1	" diameter
Dist pipe:	270	270	' long (NCPC to user)
Dist pipe:	1	1	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.44

PANGNIRTUNG	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 96250.00
-Ducting Modifications	N.A.	10100.00
-Valves, Sensors and Controllers	N.A.	12400.00
-J. W. Loop		
-Plate Heat Exchanger	9200.00	9200.00
-J. W. Recirculating Booster Pumps	3920.00	3920.00
-Control Valves and Sensors	3025.00	6050.00
-Valves	8600.00	10836.00
-Pipe and Fittings	1560.00	3120.00
-Pipe Insulation	1320.00	2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6500.00	6500.00
Distribution System		
-Outdoor Piping	40950.00	88200.00
-Valves	4100.00	7750.00
-Recirculation Pumps	4200.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	3025.00	16500.00
-Piping and Fittings	2600.00	16800.00
-Pipe Insulation	2200.00	12000.00
-Shut-Off Valves	7100.00	55000.00
-Pumps	4200.00	16800.00
Subtotal Cost	$ 102500.00	$ 378266.00
Overhead and Profit (20%)	$ 20500.00	$ 75653.20
Northern Allowance (1)	$ 86100.00	$ 317743.44
Contingency and Engineering (25%)	$ 52275.00	$ 192915.66
Total Estimated 1985 Cost	$ 261375.00	$ 964578.30

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	4	5	" diameter
Dist pipe:	525	900	' long (NCPC to user)
Dist pipe:	4	5	" diameter (NCPC to user)
No. of users:	1	4	
(3)NCI =	1.7		

PAULATUK

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 43850.00
-Ducting Modifications	N.A.	2300.00
-Valves, Sensors and Controllers	N.A.	10000.00
-J. W. Loop		
-Plate Heat Exchanger	3925.00	3925.00
-J. W. Recirculating Booster Pumps	2500.00	2500.00
-Control Valves and Sensors	1100.00	2200.00
-Valves	1380.00	1748.00
-Pipe and Fittings	300.00	600.00
-Pipe Insulation	360.00	720.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	3900.00	3900.00
Distribution System		
-Outdoor Piping	6600.00	6600.00
-Valves	660.00	660.00
-Recirculation Pumps	2750.00	2750.00
End User Connection		
-Motorized Valves, Sensors and Controls	1100.00	1100.00
-Piping and Fittings	500.00	500.00
-Pipe Insulation	600.00	600.00
-Shut-Off Valves	1060.00	1060.00
-Pumps	2750.00	2750.00
Subtotal Cost	$ 29485.00	$ 87763.00
Overhead and Profit (20%)	$ 5897.00	$ 17552.60
Northern Allowance (1)	$ 26536.50	$ 76986.70
Contingency and Engineering (25%)	$ 15479.63	$ 46075.58
Total Estimated 1985 Cost	$ 77398.13	$ 230377.88

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	1	1	" diameter
User pipe:	1	1	" diameter
Dist pipe:	165	165	' long (NCPC to user)
Dist pipe:	1	1	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.75

PELLY BAY

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	43650.00
-Ducting Modifications		N.A.		4500.00
-Valves, Sensors and Controllers		N.A.		5250.00
-J. W. Loop				
-Plate Heat Exchanger		6900.00		6900.00
-J. W. Recirculating Booster Pumps		3060.00		3060.00
-Control Valves and Sensors		2200.00		4400.00
-Valves		7635.00		9672.00
-Pipe and Fittings		900.00		1800.00
-Pipe Insulation		870.00		1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		6000.00		6000.00
Distribution System				
-Outdoor Piping		10440.00		30260.00
-valves		2360.00		2840.00
-Recirculation Pumps		3100.00		3200.00
End User Connection				
-Motorized Valves, Sensors and Controls		2175.00		4400.00
-Piping and Fittings		1338.00		3000.00
-Pipe Insulation		1150.00		2900.00
-Shut-Off Valves		4200.00		9950.00
-Pumps		3100.00		6400.00
Subtotal Cost	$	55628.00	$	150322.00
Overhead and Profit (20%)	$	11125.60	$	30064.40
Northern Allowance (1)	$	50732.74	$	137093.66
Contingency and Engineering (25%)	$	29371.58	$	79370.02
Total Estimated 1985 Cost	$	146857.92	$	396850.08

Notes:

(1) Based on the Northern Community Index (NCI).

(2) Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
user pipe:	2.5	3	" diameter
Dist pipe:	180	445	' long (NCPC to user)
Dist pipe:	2.5	3	" diameter (NCPC to user)
No. of users:	1	2	

(3) NCI = 1.76

(4) Some jacket water heat is already recovered and used. Therefore, for total JW heat recovery, assume 50% of 360' of distribution piping already exists. For JW and exhaust heat recovery alternative assume 80' of 525' of distribution piping already exists.

POND INLET

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 96250.00
-Ducting Modifications	N.A.	8800.00
-Valves, Sensors and Controllers	N.A.	12400.00
-J. W. Loop		
-Plate Heat Exchanger	11950.00	11950.00
-J. W. Recirculating Booster Pumps	4320.00	4320.00
-Control Valves and Sensors	5450.00	10900.00
-Valves	10750.00	13545.00
-Pipe and Fittings	2520.00	5040.00
-Pipe Insulation	1800.00	3600.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	7600.00	7600.00
Distribution System		
-Outdoor Piping	112710.00	154350.00
-Valves	4100.00	5350.00
-Recirculation Pumps	4200.00	4600.00
End User Connection		
-Motorized Valves, Sensors and Controls	18150.00	32700.00
-Piping and Fittings	15600.00	25200.00
-Pipe Insulation	13200.00	18000.00
-Shut-Off Valves	42600.00	53700.00
-Pumps	25200.00	27600.00
Subtotal Cost	$ 280150.00	$ 495905.00
Overhead and Profit (20%)	$ 56030.00	$ 99181.00
Northern Allowance (1)	$ 238687.80	$ 422511.06
Contingency and Engineering (25%)	$ 143716.95	$ 254399.27
Total Estimated 1985 Cost	$ 718584.75	$ 1271996.33

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	6	6	" diameter
User pipe:	4	6	" diameter
Dist pipe:	1445	1575	' long (NCFC to user)
Dist pipe:	4	6	" diameter (NCFC to user)
No. of users:	6	6	

(3)NCI = 1.71

RAE LAKES

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	15900.00
-Ducting Modifications		N.A.		1350.00
-Valves, Sensors and Controllers		N.A.		5000.00
-J. W. Loop				
-Plate Heat Exchanger		4950.00		4950.00
-J. W. Recirculating Booster Pumps		2500.00		2500.00
-Control Valves and Sensors		1200.00		2400.00
-Valves		1785.00		2250.00
-Pipe and Fittings		372.00		744.00
-Pipe Insulation		420.00		840.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		4300.00		4300.00
Distribution System				
-Outdoor Piping		7708.00		9512.00
-Valves		850.00		1070.00
-Recirculation Pumps		2750.00		3000.00
End User Connection				
-Motorized Valves, Sensors and Controls		1200.00		1260.00
-Piping and Fittings		620.00		745.00
-Pipe Insulation		700.00		700.00
-Shut-Off Valves		1480.00		1840.00
-Pumps		2750.00		3000.00
Subtotal Cost	$	33585.00	$	61361.00
Overhead and Profit (20%)	$	6717.00	$	12272.20
Northern Allowance (1)	$	18538.92	$	33871.27
Contingency and Engineering (25%)	$	14710.23	$	26876.12
Total Estimated 1985 Cost	$	73551.15	$	134380.59

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	1.5	1.5	" diameter
User pipe:	1.5	2	" diameter
Dist pipe:	164	164	' long (NCPC to user)
Dist pipe:	1.5		

RANKIN INLET		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	186500.00
-Ducting Modifications		N.A.		14900.00
-Valves, Sensors and Controllers		N.A.		21500.00
-J. W. Loop				
-Plate Heat Exchanger		9200.00		11750.00
-J. W. Recirculating Booster Pumps		3920.00		4020.00
-Control Valves and Sensors		3025.00		10900.00
-Valves		8800.00		13545.00
-Pipe and Fittings		1560.00		5040.00
-Pipe Insulation		1320.00		3600.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		6500.00		7600.00
Distribution System				
-Outdoor Piping		87000.00		129200.00
-Valves		2380.00		2340.00
-Recirculation Pumps		3100.00		3200.00
End User Connection				
-Motorized Valves, Sensors and Controls		10875.00		13200.00
-Piping and Fittings		6670.00		7900.00
-Pipe Insulation		5750.00		8700.00
-Shut-Off Valves		21000.00		29850.00
-Pumps		15500.00		19200.00
Subtotal Cost	$	186400.00	$	497045.00
Overhead and Profit (20%)	$	37280.00	$	99409.00
Northern Allowance (1)	$	131971.20	$	351907.86
Contingency and Engineering (25%)	$	88912.80	$	237090.47
Total Estimated 1985 Cost	$	444564.00	$	1185452.33

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	6	" diameter
User pipe:	2.5	3	" diameter
Dist pipe:	1500	1900	' long (NCPC to user)
Dist pipe:	2.5	3	" diameter (NCPC to user)
No. of users:	5	6	

(3)NCI = 1.59

(4)Some JW heat is presently being recovered and used for district heating of workshops and garage. Assume, therefore, that existing pipe, estimated at approximately 300' will be re-used. Therefore for JW recovery, approximately 1500' of 4" dia. pipe is required and approximately 1900' of 6" dia. pipe for JW and exhaust heat recovery scheme.

REPULSE BAY	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 43850.00
-Ducting Modifications	N.A.	2100.00
-Valves, Sensors and Controllers	N.A.	5250.00
-J. W. Loop		
-Plate Heat Exchanger	6900.00	6900.00
-J. W. Recirculating Booster Pumps	3060.00	3060.00
-Control Valves and Sensors	2200.00	4400.00
-Valves	7835.00	9872.00
-Pipe and Fittings	900.00	1800.00
-Pipe Insulation	870.00	1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6000.00	6000.00
Distribution System		
-Outdoor Piping	49590.00	91460.00
-Valves	2360.00	2840.00
-Recirculation Pumps	3100.00	3200.00
End User Connection		
-Motorized Valves, Sensors and Controls	4350.00	6600.00
-Piping and Fittings	2676.00	4500.00
-Pipe Insulation	2300.00	4350.00
-Shut-Off Valves	8400.00	14925.00
-Pumps	6200.00	9600.00
Subtotal Cost	$ 106741.00	$ 222447.00
Overhead and Profit (20%)	$ 21348.20	$ 44489.40
Northern Allowance (1)	$ 89662.44	$ 186855.48
Contingency and Engineering (25%)	$ 54437.91	$ 113447.97
Total Estimated 1985 Cost	$ 272189.55	$ 567239.85

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	2.5	3	" diameter
Dist pipe:	855	1345	' long (NCPC to user)
Dist pipe:	2.5	3	" diameter (NCPC to user)
No. of users:	2	3	
(3)NCI =	1.7		

SACHS HARBOUR

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	43850.00
-Ducting Modifications		N.A.		2100.00
-Valves, Sensors and Controllers		N.A.		5250.00
-J. W. Loop				
-Plate Heat Exchanger		6900.00		6900.00
-J. W. Recirculating Booster Pumps		3060.00		3060.00
-Control Valves and Sensors		2200.00		4400.00
-Valves		7835.00		9872.00
-Pipe and Fittings		900.00		1800.00
-Pipe Insulation		870.00		1740.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		6000.00		6000.00
Distribution System				
-Outdoor Piping		28900.00		46020.00
-Valves		2840.00		4940.00
-Recirculation Pumps		3200.00		4000.00
End User Connection				
-Motorized Valves, Sensors and Controls		4400.00		6600.00
-Piping and Fittings		3000.00		6600.00
-Pipe Insulation		2900.00		5400.00
-Shut-Off Valves		9950.00		25800.00
-Pumps		6400.00		12000.00
Subtotal Cost	$	89355.00	$	196332.00
Overhead and Profit (20%)	$	17871.00	$	39266.40
Northern Allowance (1)	$	81491.76	$	179054.78
Contingency and Engineering (25%)	$	47179.44	$	103663.30
Total Estimated 1985 Cost	$	235897.20	$	518316.48

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	3	3	" diameter
User pipe:	3	3.5	" diameter
Dist pipe:	425	590	' long (NCPC to user)
Dist pipe:	3	3.5	" diameter (NCPC to user)
No. of users:	2	3	

(3)NCI = 1.76

SNOWDRIFT	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 30850.00
-Ducting Modifications	N.A.	2100.00
-Valves, Sensors and Controllers	N.A.	5250.00
-J. W. Loop		
-Plate Heat Exchanger	6450.00	6450.00
-J. W. Recirculating Booster Pumps	2750.00	2750.00
-Control Valves and Sensors	1260.00	2520.00
-Valves	2240.00	2822.00
-Pipe and Fittings	447.00	894.00
-Pipe Insulation	420.00	840.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	5100.00	5100.00
Distribution System		
-Outdoor Piping	45820.00	45820.00
-Valves	1070.00	2360.00
-Recirculation Pumps	3000.00	3100.00
End User Connection		
-Motorized Valves, Sensors and Controls	1260.00	2175.00
-Piping and Fittings	745.00	1338.00
-Pipe Insulation	700.00	1150.00
-Shut-Off Valves	1840.00	4200.00
-Pumps	3000.00	3100.00
Subtotal Cost	$ 76102.00	$ 122819.00
Overhead and Profit (20%)	$ 15220.40	$ 24563.80
Northern Allowance (1)	$ 42008.30	$ 67796.09
Contingency and Engineering (25%)	$ 33332.68	$ 53794.72
Total Estimated 1985 Cost	$ 166663.38	$ 268973.61

Notes:

(1)Based on the Northern Community Index (NCI).

(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	2	2	" diameter
User pipe:	2	2.5	" diameter
Dist pipe:	790	790	' long (NCPC to user)
Dist pipe:	2	2.5	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.46

SPENCE BAY

	Jacket Water Heat Recovery Only	Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant		
-Exhaust System		
-Heat Recovery Silencer	$ N.A.	$ 96250.00
-Ducting Modifications	N.A.	3150.00
-Valves, Sensors and Controllers	N.A.	6450.00
-J. W. Loop		
-Plate Heat Exchanger	9200.00	9200.00
-J. W. Recirculating Booster Pumps	3920.00	3920.00
-Control Valves and Sensors	3025.00	6050.00
-Valves	8600.00	10836.00
-Pipe and Fittings	1560.00	3120.00
-Pipe Insulation	1320.00	2640.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements	6500.00	6500.00
Distribution System		
-Outdoor Piping	54990.00	69090.00
-Valves	4940.00	7750.00
-Recirculation Pumps	4000.00	4200.00
End User Connection		
-Motorized Valves, Sensors and Controls	2200.00	4125.00
-Piping and Fittings	2200.00	4200.00
-Pipe Insulation	1800.00	3000.00
-Shut-Off Valves	8600.00	13750.00
-Pumps	4000.00	4200.00
Subtotal Cost	$ 116855.00	$ 258431.00
Overhead and Profit (20%)	$ 23371.00	$ 51686.20
Northern Allowance (1)	$ 112180.80	$ 248093.76
Contingency and Engineering (25%)	$ 63101.70	$ 139552.74
Total Estimated 1985 Cost	$ 315508.50	$ 697763.70

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	4	4	" diameter
User pipe:	3.5	5	" diameter
Dist pipe:	705	705	' long (NCPC to user)
Dist pipe:	3.5	5	" diameter (NCPC to user)
No. of users:	1	1	

(3)NCI = 1.8

WHALE COVE

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	43850.00
-Ducting Modifications		N.A.		2100.00
-Valves, Sensors and Controllers		N.A.		5250.00
-J. W. Loop				
-Plate Heat Exchanger		6450.00		6450.00
-J. W. Recirculating Booster Pumps		2850.00		2850.00
-Control Valves and Sensors		2175.00		4350.00
-Valves		5060.00		6375.00
-Pipe and Fittings		803.00		1605.00
-Pipe Insulation		690.00		1380.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		5500.00		5500.00
Distribution System				
-Outdoor Piping		41760.00		47560.00
-Valves		1070.00		2360.00
-Recirculation Pumps		3000.00		3100.00
End User Connection				
-Motorized Valves, Sensors and Controls		1260.00		4350.00
-Piping and Fittings		745.00		2676.00
-Pipe Insulation		700.00		2300.00
-Shut-Off Valves		1840.00		8400.00
-Pumps		3000.00		6200.00
Subtotal Cost	$	76903.00	$	156656.00
Overhead and Profit (20%)	$	15380.60	$	31331.20
Northern Allowance (1)	$	59984.34	$	122191.68
Contingency and Engineering (25%)	$	38066.99	$	77544.72
Total Estimated 1985 Cost	$	190334.93	$	387723.60

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust Heat Rec	
JW Loop:	2.5	2.5	" diameter
User pipe:	2	2.5	" diameter
Dist pipe:	720	820	' long (NCPC to user)
Dist pipe:	2	2.5	" diameter (NCPC to user)
No. of users:	1	2	

(3)NCI = 1.65

WRIGLEY

		Jacket Water Heat Recovery Only		Jacket Water Plus Exhaust Gas Heat Recovery
Modifications to NCPC Plant				
-Exhaust System				
-Heat Recovery Silencer	$	N.A.	$	20900.00
-Ducting Modifications		N.A.		1350.00
-Valves, Sensors and Controllers		N.A.		5000.00
-J. W. Loop				
-Plate Heat Exchanger		4950.00		4950.00
-J. W. Recirculating Booster Pumps		2500.00		2500.00
-Control Valves and Sensors		1200.00		2400.00
-Valves		1785.00		2250.00
-Pipe and Fittings		372.00		744.00
-Pipe Insulation		420.00		840.00
-BTU Meter, Complete with Temperature and Flow Sensor Elements		4300.00		4300.00
Distribution System				
-Outdoor Piping		10810.00		74240.00
-Valves		850.00		1070.00
-Recirculation Pumps		2750.00		3000.00
End User Connection				
-Motorized Valves, Sensors and Controls		1200.00		2520.00
-Piping and Fittings		620.00		1490.00
-Pipe Insulation		700.00		1400.00
-Shut-Off Valves		1480.00		3680.00
-Pumps		2750.00		6000.00
Subtotal Cost	$	36687.00	$	138634.00
Overhead and Profit (20%)	$	7337.40	$	27726.80
Northern Allowance (1)	$	19370.74	$	73198.75
Contingency and Engineering (25%)	$	15848.78	$	59889.89
Total Estimated 1985 Cost	$	79243.92	$	299449.44

Notes:
(1)Based on the Northern Community Index (NCI).
(2)Costs based on the following pipe diameters and lengths :

	JW Rec Only	JW and Exhaust .Heat Rec	
JW Loop:	1.5	1.5	" diameter
User pipe:	1.5	2	" diameter
Dist pipe:	230	1280	' long (NCPC to user)
Dist pipe:	1.5	2	" diameter (NCPC to user)
No. of users:	1	2	

(3)NCI = 1.44

APPENDIX "E.2"

ANNUAL FUEL SAVINGS - DETAILED CALCULATIONS

FUEL COST SAVINGS USING 45% OF AVAILABLE JACKET WATER HEAT

SITE	FUEL COST $/LITRE	JW HEAT @ 45% UTILIZATION kW	DEGREE DAYS DEG C	DESIGN TEMP DIFF DEG C	EQUIVALENT FUEL OIL CONSUMED L/YEAR	ANNUAL FUEL OIL SAVINGS $
AKLAVIK	0.49	137	9849	71	50362	24677.33
ARCTIC BAY	0.54	77	11693	71	33554	18119.23
ARCTIC RED RIVER	0.49	23	9604	77	7721	3783.41
BAKER LAKE	0.55	237	10990	71	97102	53405.98
BROUGHTON ISLAND	0.47	66	10691	64	29358	13798.35
CAMBRIDGE BAY	0.74	279	12036	74	120281	89007.69
CAPE DORSET	0.53	151	10751	74	58221	30857.11
CHESTERFIELD INLET	0.54	46	10768	72	18349	9908.28
CLYDE RIVER	0.51	92	11006	68	39651	20222.07
COPPERMINE	0.56	164	10758	71	65637	36666.47
CORAL HARBOUR	0.55	156	10751	74	59917	32954.40
ESKIMO POINT	0.54	191	8100	77	53314	28789.31
FORT FRANKLIN	0.57	81	9633	77	26981	15379.89
FORT GOOD HOPE	0.46	71	9633	77	23482	10801.62
FORT LIARD	0.52	38	7389	68	11015	5727.94
FORT McPHERSON	0.44	138	9804	77	46591	20500.21
FORT NORMAN	0.46	68	8902	75	21424	9854.93
FORT SIMPSON	0.42	322	8100	77	89765	37701.21
GJOA HAVEN	0.65	102	12125	75	43800	28470.11
GRISE FIORD	0.55	32	12861	78	13842	7613.32
HALL BEACH	0.54	68	11810	75	28505	15392.62
HOLMAN ISLAND	0.58	61	11086	67	26829	15560.83
IGLOOLIK	0.51	145	12147	73	64002	32640.82
JEAN MARIE RIVER	0.56	3	8100	77	891	499.19
LAC LA MATRE	0.56	36	8529	72	11160	6249.57
LAKE HARBOUR	0.51	60	10751	74	23246	11855.70
NAHANNI BUTTE	0.53	6	11154	70	2333	1236.29
PANGNIRTUNG	0.52	156	9623	77	51700	26884.04
PAULATUK	0.56	38	9623	77	12556	7031.22
PELLY BAY	0.76	54	12125	75	23209	17638.48
POND INLET	0.53	169	12102	74	73161	38775.53
RAE LAKES	0.64	16	10990	72	6371	4077.52
RANKIN INLET	0.54	428	8529	72	134348	72548.04
REPULSE BAY	0.53	66	9804	77	22210	11771.34
SACHS HARBOUR	0.57	71	11682	73	29976	17086.32
SNOWDRIFT	0.47	31	8100	77	8693	4085.86
SPENCE BAY	0.65	117	12147	73	51407	33414.76
WHALE COVE	0.53	43	10751	71	17146	9087.17
WRIGLEY	0.47	23	8464	74	6944	3263.52

$$\text{FUEL COST SAVINGS} = \frac{\text{RESIDUAL HEAT AVAILABLE} * \text{DEGREE DAYS} * 24}{\text{DESIGN TEMP DIFFERENCE} * n * V} * \text{CD} * \text{FUEL OIL COST}$$

WHERE : n = CORRECTION FACTOR (0.65)
V = HEATING VALUE OF FUEL (9.76 kW/L)
CD = CORRECTION FACTOR FOR HEATING EFFECT VS DEGREE DAYS (0.7)

FUEL COST SAVINGS USING 100% OF AVAILABLE JACKET WATER HEAT

SITE	FUEL COST $/LITRE	JW HEAT @ 100% UTILIZATION kW	DEGREE DAYS DEG C	DESIGN TEMP DIFF DEG C	FUEL OIL CONSUMED CONSUMED L/YEAR	ANNUAL FUEL OIL COST $
AKLAVIK	0.49	305	9849	71	111915	54838.52
ARCTIC BAY	0.54	171	11693	71	74565	40264.96
ARCTIC RED RIVER	0.49	51	9804	77	17158	8407.58
BAKER LAKE	0.55	526	10990	71	215782	118679.96
BROUGHTON ISLAND	0.47	147	10691	64	65240	30663.01
CAMBRIDGE BAY	0.74	620	12036	74	267290	197794.86
CAFE DORSET	0.53	336	10751	74	129380	68571.36
CHESTERFIELD INLET	0.54	103	10768	72	40775	22018.40
CLYDE RIVER	0.51	205	11006	68	88114	44937.94
COPPERMINE	0.56	364	10758	71	146303	81929.92
CORAL HARBOUR	0.55	346	10751	74	133149	73232.01
ESKIMO POINT	0.54	425	8100	77	118475	63976.25
FORT FRANKLIN	0.57	181	9633	77	59957	34175.31
FORT GOOD HOPE	0.46	157	9633	77	52182	24003.61
FORT LIARD	0.52	85	7389	66	24478	12728.75
FORT McPHERSON	0.44	307	9804	77	103536	45556.02
FORT NORMAN	0.46	151	8902	75	47608	21899.85
FORT SIMPSON	0.42	716	8100	77	199477	83780.47
GJOA HAVEN	0.65	227	12125	75	97334	63266.90
GRISE FIORD	0.55	70	12861	78	30761	16918.48
HALL BEACH	0.54	152	11810	75	63344	34205.82
HOLMAN ISLAND	0.58	136	11086	67	59620	34579.62
ISLOOLIK	0.51	323	12147	73	142226	72535.15
JEAN MARIE RIVER	0.56	7	8100	77	1981	1109.31
LAC LA MATRE	0.56	79	8529	72	24800	13887.93
LAKE HARBOUR	0.51	134	10751	74	51659	26345.99
NAHANNI BUTTE	0.53	12	11184	70	5184	2747.32
PANGNIRTUNG	0.52	347	9623	77	114889	59742.31
PAULATUK	0.56	84	9623	77	27902	15624.94
PELLY BAY	0.76	120	12125	75	51575	39196.63
POND INLET	0.53	375	12102	74	162581	86167.83
RAE LAKES	0.64	35	10990	72	14158	9061.16
RANKIN INLET	0.54	951	8529	72	298552	161217.87
REPULSE BAY	0.53	146	9804	77	49356	26158.53
SACHS HARBOUR	0.57	157	11682	73	66613	37969.59
SNOWDRIFT	0.47	69	8100	77	19319	9079.70
SPENCE BAY	0.65	259	12147	73	114239	74255.03
WHALE COVE	0.53	95	10751	71	38101	20193.72
WRIGLEY	0.47	51	8464	74	15430	7252.27

$$\text{FUEL COST SAVINGS} = \frac{\text{RESIDUAL HEAT AVAILABLE} * \text{DEGREE DAYS} * 24}{\text{DESIGN TEMP DIFFERENCE} * n * V} * \text{CD} * \text{FUEL OIL COST}$$

WHERE : n = CORRECTION FACTOR (0.65)
V = HEATING VALUE OF FUEL (9.76 kW/L)
CD = CORRECTION FACTOR FOR HEATING EFFECT VS DEGREE DAYS (0.7)

FUEL COST SAVINGS USING 55% OF AVAILABLE JACKET WATER AND EXHAUST HEAT

SITE	FUEL COST $/LITRE	TOTAL HEAT @ 55% UTILIZATION kW	DEGREE DAYS DEG C	DESIGN TEMP DIFF DEG C	EQUIVALENT FUEL OIL CONSUMED L/YEAR	ANNUAL FUEL OIL COST $
AKLAVIK	0.49	274	9849	71	100724	49354.67
ARCTIC BAY	0.54	134	11693	71	67108	36238.47
ARCTIC RED RIVER	0.49	46	9804	77	15442	7566.82
BAKER LAKE	0.55	473	10990	71	194204	106811.97
BROUGHTON ISLAND	0.47	133	10691	64	58716	27596.71
CAMBRIDGE BAY	0.74	558	12036	74	240561	178015.37
CAPE DORSET	0.53	302	10751	74	116442	61714.23
CHESTERFIELD INLET	0.54	93	10768	72	36697	19816.56
CLYDE RIVER	0.51	185	11006	68	79302	40444.15
COPPERMINE	0.56	328	10758	71	131673	73736.93
CORAL HARBOUR	0.55	311	10751	74	119834	65908.81
ESKIMO POINT	0.54	382	8100	77	106627	57578.62
FORT FRANKLIN	0.57	163	9633	77	53961	30757.78
FORT GOOD HOPE	0.46	142	9633	77	46964	21603.25
FORT LIARD	0.52	77	7389	68	22031	11455.88
FORT McPHERSON	0.44	276	9804	77	93183	41000.42
FORT NORMAN	0.46	136	8902	75	42848	19709.87
FORT SIMPSON	0.42	644	8100	77	179530	75402.42
GJOA HAVEN	0.65	204	12125	75	87600	56940.21
GRISE FIORD	0.55	63	12861	78	27685	15226.63
HALL BEACH	0.54	137	11810	75	57010	30785.24
HOLMAN ISLAND	0.58	122	11086	67	53658	31121.66
IGLOOLIK	0.51	290	12147	73	128003	65281.63
JEAN MARIE RIVER	0.56	6	8100	77	1783	998.38
LAC LA MARTRE	0.56	71	8529	72	22320	12499.14
LAKE HARBOUR	0.51	121	10751	74	46493	23711.39
NAHANNI BUTTE	0.53	11	11184	70	4665	2472.58
PANGNIRTUNG	0.52	312	9623	77	103400	53768.08
PAULATUK	0.56	76	9623	77	25112	14062.45
PELLY BAY	0.76	108	12125	75	46417	35276.97
POND INLET	0.53	338	12102	74	146323	77551.05
RAE LAKES	0.64	32	10990	72	12742	8155.05
RANKIN INLET	0.54	856	8529	72	268696	145096.08
REPULSE BAY	0.53	132	9804	77	44420	23542.68
SACHS HARBOUR	0.57	141	11682	73	59952	34172.64
SNOWDRIFT	0.47	62	8100	77	17387	8171.73
SPENCE BAY	0.65	233	12147	73	102815	66829.53
WHALE COVE	0.53	85	10751	71	34291	18174.35
WRIGLEY	0.47	46	8464	74	13887	6527.04

$$\text{FUEL COST SAVINGS} = \frac{\text{RESIDUAL HEAT AVAILABLE} * \text{DEGREE DAYS} * 24}{\text{DESIGN TEMP DIFFERENCE} * n * V} * \text{CD} * \text{FUEL OIL COST}$$

WHERE : n = CORRECTION FACTOR (0.65)
V = HEATING VALUE OF FUEL (9.76 kW/L)
CD = CORRECTION FACTOR FOR HEATING EFFECT VS DEGREE DAYS (0.7)

FUEL COST SAVINGS USING 100% OF AVAILABLE JACKET WATER AND EXHAUST HEAT

SITE	FUEL COST $/LITRE	TOTAL HEAT @ 100% UTILIZATION kW	DEGREE DAYS DEG C	DESIGN TEMP DIFF DEG C	EQUIVALENT FUEL OIL CONSUMED L/YEAR	ANNUAL FUEL OIL COST $
AKLAVIK	0.49	499	9849	71	183134	89735.76
ARCTIC BAY	0.54	280	11693	71	122015	65888.12
ARCTIC RED RIVER	0.49	83	9804	77	28077	13757.86
BAKER LAKE	0.55	861	10990	71	353097	194203.58
BROUGHTON ISLAND	0.47	241	10691	64	106757	50175.83
CAMBRIDGE BAY	0.74	1015	12036	74	437384	323664.31
CAPE DORSET	0.53	550	10751	74	211713	112207.69
CHESTERFIELD INLET	0.54	168	10768	72	66722	36030.11
CLYDE RIVER	0.51	336	11006	68	144186	73534.82
COPPERMINE	0.56	596	10758	71	239406	134067.15
CORAL HARBOUR	0.55	566	10751	74	217880	119834.19
ESKIMO POINT	0.54	695	8100	77	193867	104688.41
FORT FRANKLIN	0.57	296	9633	77	98111	55923.24
FORT GOOD HOPE	0.46	258	9633	77	85388	39278.63
FORT LIARD	0.52	139	7389	68	40056	20828.86
FORT McPHERSON	0.44	502	9804	77	169423	74546.21
FORT NORMAN	0.46	248	8902	75	77905	35836.12
FORT SIMPSON	0.42	1171	8100	77	326417	137095.32
GJOA HAVEN	0.65	372	12125	75	159273	103527.66
GRISE FIORD	0.55	115	12861	78	50336	27684.79
HALL BEACH	0.54	248	11810	75	103654	55973.16
HOLMAN ISLAND	0.58	222	11086	67	97560	56584.83
IGLOOLIK	0.51	528	12147	73	232733	118693.88
JEAN MARIE RIVER	0.56	12	8100	77	3241	1815.24
LAC LA MARTRE	0.56	129	8529	72	40582	22725.71
LAKE HARBOUR	0.51	220	10751	74	84533	43111.62
NAHANNI BUTTE	0.53	20	11184	70	8482	4495.61
PANGNIRTUNG	0.52	568	9623	77	188000	97760.15
PAULATUK	0.56	138	9623	77	45657	25568.09
PELLY BAY	0.76	197	12125	75	84395	64139.94
POND INLET	0.53	614	12102	74	266041	141001.91
RAE LAKES	0.64	57	10990	72	23168	14827.36
RANKIN INLET	0.54	1556	8529	72	488539	263811.05
REPULSE BAY	0.53	239	9804	77	80764	42804.87
SACHS HARBOUR	0.57	257	11682	73	109004	62132.06
SNOWDRIFT	0.47	113	8100	77	31612	14857.68
SPENCE BAY	0.65	424	12147	73	186936	121508.23
WHALE COVE	0.53	155	10751	71	62348	33044.27
WRIGLEY	0.47	83	8464	74	25250	11867.34

$$\text{FUEL COST SAVINGS} = \frac{\text{RESIDUAL HEAT AVAILABLE} * \text{DEGREE DAYS} * 24}{\text{DESIGN TEMP DIFFERENCE} * n * V} * \text{CD} * \text{FUEL OIL COST}$$

WHERE : n = CORRECTION FACTOR (0.65)
V = HEATING VALUE OF FUEL (9.76 kW/L)
CD = CORRECTION FACTOR FOR HEATING EFFECT VS DEGREE DAYS (0.7)

APPENDIX "E.3"

PAYBACK PERIOD - DETAILED CALCULATIONS

COST EVALUATION FOR JW HEAT RECOVERY @ 45% UTILIZATION

SITE	CAPITAL $	ANNUAL COSTS MAINTENANCE $	ANNUAL COSTS OPERATING $	ANNUAL ENERGY COST SAVINGS $	PAY BACK PERIOD YEARS
AKLAVIK	307504.00	6150.08	5904.00	24677.32	24.36
ARCTIC BAY	285811.00	5716.22	4368.00	18119.23	35.57
ARCTIC RED RIVER	106880.00	2137.60	1456.00	3783.41	563.09
BAKER LAKE	1220679.00	24413.58	8736.00	53405.98	60.26
BROUGHTON ISLAND	196901.00	3938.02	2902.00	13796.35	28.30
CAMBRIDGE BAY	NA	0.00	8736.00	69007.69	0.00
CAPE DORSET	437655.00	8753.10	5904.00	30857.11	27.02
CHESTERFIELD INLET	572190.00	11443.80	2902.00	[illegible]	-128.54
CLYDE RIVER	765411.00	15308.22	5624.00	20022.07	-840.93
COPPERMINE	608807.00	12176.14	8736.00	36820.47	38.27
CORAL HARBOUR	500291.00	10005.82	8736.00	32954.40	35.20
ESKIMO POINT	398356.00	7967.12	8736.00	28769.31	33.01
FORT FRANKLIN	223177.00	4463.54	5624.00	15176.89	43.85
FORT GOOD HOPE	264970.00	5299.40	2902.00	10801.62	101.79
FORT LIARD	114746.00	2294.92	2902.00	5727.74	216.07
FORT McPHERSON	213248.00	4264.96	5624.00	20300.21	20.48
FORT NORMAN	223038.00	4460.76	2902.00	9854.93	89.50
FORT SIMPSON	688006.00	13760.12	8736.00	37701.21	45.25
GJOA HAVEN	525495.00	10509.90	5824.00	28470.11	43.30
GRISE FIORD	212231.00	4244.62	2902.00	7613.32	454.75
HALL BEACH	323331.00	6466.62	4368.00	15392.62	70.94
HOLMAN	468799.00	9375.98	4368.00	15560.83	258.03
IGLOOLIK	196469.00	3929.38	5804.00	32640.82	8.58
JEAN MARIE RIVER	NA	0.00	364.00	499.19	0.00
LAC LA MARTRE	NA	0.00	1456.00	6245.37	0.00
LAKE HARBOUR	146451.00	2929.02	2902.00	11855.70	24.31
NAHANNI BUTTE	72760.00	1455.20	364.00	1236.29	-124.82
PANGNIRTUNG	261375.00	5227.50	5802.00	26884.04	16.49
PAULATUK	77398.00	1547.96	364.00	7031.22	15.12
PELLY BAY	146858.00	2937.16	2902.00	17638.45	12.45
POND INLET	718585.00	14371.70	5804.00	38775.52	38.63
RAE LAKES	73551.00	1471.02	728.00	4077.32	39.16
RANKIN INLET	444564.00	8891.28	1456.00	72348.04	7.17
REPULSE BAY	272190.00	5443.80	2902.00	11771.74	79.46
SACHS HARBOUR	235897.00	4717.94	2902.00	17066.32	24.97
SNOWDRIFT	166664.00	3333.28	1456.00	4065.86	-230.39
SPENCE BAY	315508.00	6310.16	5904.00	33414.76	14.88
WHALE COVE	190334.00	3806.68	2901.00	9087.17	79.99
WRIGLEY	79244.00	1584.88	728.00	3263.52	83.36

COST EVALUATION FOR JW HEAT RECOVERY @ 100% UTILIZATION

SITE	CAPITAL $	ANNUAL COSTS MAINTENANCE $	 OPERATING $	ANNUAL ENERGY COST SAVINGS $	PAY BACK PERIOD YEARS
AKLAVIK	307504.00	6150.08	5904.00	54636.52	7.19
ARCTIC BAY	285811.00	5716.22	4368.00	40264.95	9.47
ARCTIC RED RIVER	106880.00	2137.60	1456.00	8407.38	22.20
BAKER LAKE	1220698.00	24413.96	8736.00	118679.95	14.27
BROUGHTON ISLAND	196901.00	3938.02	2902.00	30663.01	8.27
CAMBRIDGE BAY	NA	0.00	8736.00	197794.86	0.00
CAPE DORSET	437655.00	8753.10	5904.00	68571.36	8.12
CHESTERFIELD INLET	572190.00	11443.80	2902.00	22016.40	74.58
CLYDE RIVER	765411.00	15308.22	5824.00	44937.94	32.15
COPPERMINE	609807.00	12196.14	8736.00	81929.72	10.00
CORAL HARBOUR	500291.00	10005.82	8736.00	73232.01	9.18
ESKIMO POINT	399556.00	7991.12	8736.00	63976.25	8.45
FORT FRANKLIN	223177.00	4463.54	5824.00	34175.31	9.34
FORT GOOD HOPE	264970.00	5299.40	2902.00	24003.81	16.77
FORT LIARD	114746.00	2294.92	2902.00	12728.75	15.23
FORT McPHERSON	213246.00	4264.96	5824.00	45555.02	6.01
FORT NORMAN	223038.00	4460.76	2902.00	21899.25	15.34
FORT SIMPSON	688006.00	13760.12	8736.00	83760.47	11.23
GJOA HAVEN	525495.00	10509.90	5824.00	63266.99	11.20
GRISE FIORD	212231.00	4244.62	2902.00	16918.48	21.72
HALL BEACH	323331.00	6466.62	4368.00	34205.32	13.83
HOLMAN	468799.00	9375.98	4368.00	34579.82	22.50
IGLOOLIK	196469.00	3929.38	5804.00	72535.15	3.13
JEAN MARIE RIVER	NA	0.00	364.00	1109.31	0.00
LAC LA MARTRE	NA	0.00	1456.00	13887.93	0.00
LAKE HARBOUR	146451.00	2929.02	2902.00	26545.99	[illegible]
NAHANNI BUTTE	72760.00	1455.20	364.00	2747.32	78.40
PANGNIRTUNG	261375.00	5227.50	5802.00	59742.31	5.37
PAULATUK	77398.00	1547.96	364.00	15624.94	5.64
PELLY BAY	146858.00	2937.16	2902.00	37173.83	4.49
POND INLET	718585.00	14371.70	5904.00	66157.83	16.27
RAE LAKES	73551.00	1471.02	728.00	9051.16	[illegible]
RANKIN INLET	444564.00	8891.28	1456.00	161217.37	2.95
REPULSE BAY	272190.00	5443.80	2902.00	26158.57	15.28
SACHS HARBOUR	235897.00	4717.94	2902.00	37959.59	[illegible]
SNOWDRIFT	166664.00	3333.28	1456.00	9079.70	38.85
SPENCE BAY	315508.00	6310.16	5904.00	74255.03	5.09
WHALE COVE	190334.00	3806.68	2901.00	20193.72	14.11
WRIGLEY	79244.00	1584.88	728.00	7252.27	16.04

COST EVALUATION FOR JW AND EXHAUST HEAT RECOVERY @ 55% UTILIZATION

SITE	CAPITAL $	ANNUAL COSTS MAINTENANCE $	OPERATING $	ANNUAL ENERGY COST SAVINGS $	PAY BACK PERIOD YEARS
AKLAVIK	671633.00	13432.66	8736.00	49354.67	24.71
ARCTIC BAY	775647.00	15516.98	5824.00	36235.47	52.08
ARCTIC RED RIVER	226577.00	4531.54	2912.00	7566.82	1699.96
BAKER LAKE	1715276.00	34305.52	14560.00	106211.77	29.60
BROUGHTON ISLAND	607535.00	12150.70	5824.00	27596.71	63.01
CAMBRIDGE BAY	NA	0.00	14560.00	178015.37	0.00
CAPE DORSET	641301.00	12826.02	8736.00	61714.23	15.97
CHESTERFIELD INLET	670166.00	13403.36	4368.00	19616.56	327.66
CLYDE RIVER	1216152.00	24323.04	5824.00	40444.15	118.11
COPPERMINE	1208840.00	24176.80	8736.00	77736.93	27.61
CORAL HARBOUR	772684.00	15453.66	8736.00	65908.81	18.52
ESKIMO POINT	1060860.00	21217.20	14560.00	57578.62	49.66
FORT FRANKLIN	526696.00	10533.92	5824.00	30757.79	36.38
FORT GOOD HOPE	607179.00	12143.58	4368.00	21603.25	119.25
FORT LIARD	241315.00	4826.30	4368.00	11455.86	106.70
FORT McPHERSON	544569.00	10891.38	8736.00	41000.42	25.48
FORT NORMAN	423511.00	8470.22	4368.00	19709.87	61.83
FORT SIMPSON	1250600.00	25012.00	14560.00	75402.42	34.90
GJOA HAVEN	842999.00	16859.98	8736.00	56940.21	26.89
GRISE FIORD	472118.00	9442.36	2912.00	15226.63	163.39
HALL BEACH	507374.00	10147.48	5824.00	30785.24	34.26
HOLMAN	436687.00	8733.74	5824.00	31121.66	26.[illegible]
IGLOOLIK	739335.00	14786.70	8736.00	65251.83	[illegible]
JEAN MARIE RIVER	NA	0.00	728.00	998.38	0.00
LAC LA MARTRE(ACTUAL)(2)	250000.00	5000.00	2912.00	26300.00	13.81
(THEORETICAL)(2)	254000.00	5080.00	2912.00	12499.13	56.23
LAKE HARBOUR	410711.00	8214.22	4368.00	23711.39	36.90
NAHANNI BUTTE	125416.00	2508.32	728.00	2472.58	-164.21
PANGNIRTUNG	964578.00	19291.56	8736.00	53788.08	37.[illegible]
PAULATUK	230378.00	4607.36	728.00	14692.45	28.[illegible]
PELLY BAY	396850.00	7937.00	4368.00	35276.97	17.[illegible]
POND INLET	1271996.00	25439.92	8736.00	77551.[illegible]	29.[illegible]
RAE LAKES	134380.00	2687.60	1456.00	8155.[illegible]	[illegible]
RANKIN INLET	1195452.00	23909.04	2912.00	145096.36	10.01
REPULSE BAY	567240.00	11344.80	4368.00	23542.68	72.45
SACHS HARBOUR	518316.00	10366.32	4368.00	34172.89	26.89
SNOWDRIFT	268974.00	5379.48	1456.00	8171.73	201.29
SPENCE BAY	697764.00	13955.28	8736.00	66829.53	15.81
WHALE COVE	387724.00	7754.48	2912.00	18174.[illegible]	51.[illegible]
WRIGLEY	299449.00	5988.98	1456.00	6327.04	-[illegible]

NOTES: 1)ANALYSIS BASED ON A 20 YEAR PERIOD.
(2)ACTUAL REPRESENTS FIGURES FROM "AS-CONSTRUCTED" SYSTEM.
THEORETICAL REPRESENTS FIGURES CALCULATED BASED ON THE SAME
ESTIMATING TECHNIQUES USED FOR ALL OTHER SITES.

COST EVALUATION FOR JW AND EXHAUST HEAT RECOVERY @ 100% UTILIZATION

SITE	CAPITAL $	ANNUAL COSTS MAINTENANCE $	ANNUAL COSTS OPERATING $	ANNUAL ENERGY COST SAVINGS $	PAY BACK PERIOD YEARS
AKLAVIK	671633.00	13432.66	8736.00	89735.76	9.94
ARCTIC BAY	775849.00	15516.98	5824.00	65888.12	17.42
ARCTIC RED RIVER	226577.00	4531.54	2902.00	13757.86	35.83
BAKER LAKE	1715276.00	34305.52	14560.00	194203.58	11.80
BROUGHTON ISLAND	607535.00	12150.70	5804.00	50175.83	18.86
CAMBRIDGE BAY	NA	0.00	14560.00	323664.31	0.00
CAPE DORSET	641301.00	12826.02	8736.00	112207.69	7.07
CHESTERFIELD INLET	670166.00	13403.36	4368.00	36030.11	36.70
CLYDE RIVER	1216152.00	24323.04	5824.00	73534.82	28.03
COPPERMINE	1208840.00	24176.80	8736.00	134067.15	11.95
CORAL HARBOUR	772684.00	15453.68	8736.00	119834.19	8.08
ESKIMO POINT	1060860.00	21217.20	14560.00	104682.41	15.39
FORT FRANKLIN	526696.00	10533.92	5824.00	55923.24	13.31
FORT GOOD HOPE	607179.00	12143.58	4368.00	39276.63	26.67
FORT LIARD	241315.00	4826.30	4368.00	20828.86	20.74
FORT McPHERSON	544569.00	10891.38	8736.00	74546.21	9.92
FORT NORMAN	423511.00	8470.22	4368.00	38636.12	16.42
FORT SIMPSON	1250600.00	25012.00	14560.00	137095.32	12.82
GJOA HAVEN	842999.00	16859.98	8736.00	103527.66	10.82
GRISE FIORD	472118.00	9442.36	2902.00	27684.79	30.78
HALL BEACH	507374.00	10147.48	5804.00	55973.16	12.68
HOLMAN	436667.00	8733.34	5804.00	56584.83	10.39
IGLOOLIK	739335.00	14786.70	8736.00	118693.88	7.77
JEAN MARIE RIVER	NA	0.00	728.00	1815.24	0.00
LAC LA MARTRE ACTUAL(2)	250000.00	5000.00	2902.00	26000.00	13.81
(THEORETICAL)(2)	254300.00	5086.00	2902.00	22725.70	17.26
LAKE HARBOUR	410711.00	8214.22	4368.00	43111.82	13.45
NAHANNI BUTTE	125416.00	2508.32	728.00	4495.61	99.59
PANGNIRTUNG	964578.00	19291.56	8736.00	97760.12	13.83
PAULATUK	230378.00	4607.56	728.00	25566.09	11.39
PELLY BAY	396850.00	7937.00	4368.00	64139.74	7.66
POND INLET	1271996.00	25439.92	8736.00	141001.91	11.91
RAE LAKES	134350.00	2687.00	1456.00	14627.36	12.81
RANKIN INLET	1185452.00	23709.04	2902.00	263811.05	5.00
REPULSE BAY	567240.00	11344.80	4368.00	42804.87	20.94
SACHS HARBOUR	518316.00	10366.32	4368.00	62132.38	10.94
SNOWDRIFT	268974.00	5379.48	1456.00	14857.68	33.53
SPENCE BAY	697764.00	13955.28	8736.00	121508.23	7.06
WHALE COVE	387724.00	7754.48	2902.00	33044.27	17.32
WRIGLEY	299448.00	5988.96	1456.00	11867.34	67.71

NOTES: (1) ANALYSIS BASED ON A 20 YEAR PERIOD.
(2) ACTUAL REPRESENTS FIGURES FROM "AS-CONSTRUCTED" SYSTEM.
THEORETICAL REPRESENTS FIGURES CALCULATED BASED ON THE SAME ESTIMATING TECHNIQUES USED FOR ALL OTHER SITES.